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CONTRIBUTIONS TO PALEONTOLOGY

STUDIES OF CENOZOIC VERTEBRATES AND STRATIGRAPHY OF WESTERN NORTH AMERICA

PAUL C. HENSHAW
ROBERT W. WILSON
HILDEGARDE HOWARD
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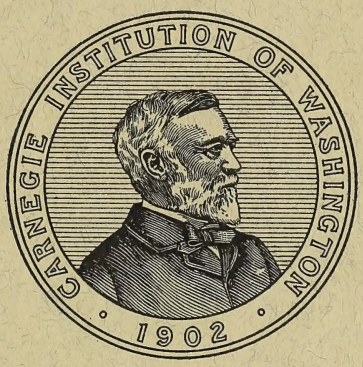

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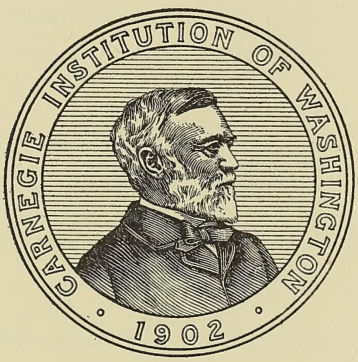

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CONTRIBUTIONS TO PALEONTOLOGY

I

A TERTIARY MAMMALIAN FAUNA FROM THE AVAWATZ MOUNTAINS, SAN BERNARDINO COUNTY, CALIFORNIA

By Paul C. Henshaw

With six plates and three text figures

[Issued May 18, 1939]

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A TERTIARY MAMMALIAN FAUNA FROM THE AVAWATZ MOUNTAINS, SAN BERNARDINO COUNTY, CALIFORNIA

INTRODUCTION

The Tertiary mammal occurrence in the Avawatz Mountains, discovered in 1932 by the late H. W. Nickerson of Yucca Grove, California, was reported first to the Los Angeles County Museum. W. M. Strong, sent out by the Museum to make a survey of the area, assembled a small collection, but the material was so fragmentary that interest subsided. Subsequently, in 1935, in the course of archæological field studies, Mr. and Mrs. William

FIG. 1—Locations of upper Miocene and lower Pliocene vertebrate fossil localities of the western United States.

H. Campbell of Twenty-nine Palms rediscovered the fossiliferous locality on the south flank of the Avawatz Mountains. The occurrence was brought to the attention of E. L. Furlong, who visited the region with Mr. and Mrs. Campbell. Most of the material now in the collections of the California Institute of Technology was acquired during these visits. Since then, several brief collecting trips have been made to the area.

The significance of the discovery of fossil vertebrate material in the Avawatz Mountains becomes at once apparent when it is recognized that herein lies a clue to the dating of at least some of the tremendous diastrophic activity which has spasmodically convulsed the western portion of the Great Basin during later Tertiary time. This point will be discussed further in the section dealing with the geological observations.

My sincere thanks are extended to Mr. and Mrs. W. H. Campbell for their wholehearted cooperation in obtaining the collection. I am deeply indebted to Dr. Chester Stock for his continued interest, invaluable counsel, and critical reading of the manuscript. The guidance and advice of E. L. Furlong, who assembled the bulk of the collection, of R. W. Wilson, who studied and described the Avawatz rodents, and of J. R. Schultz are acknowledged with gratitude. J. F. Dougherty, A. B. Drescher, and G. A. Rynearson of the California Institute of Technology ably assisted in collecting material. For their courtesy, cooperation, and helpful suggestions I am greatly obligated to the staff of the University of California, especially to J. T. Gregory, R. A. Stirton, and V. L. Vander Hoof. The illustrations were prepared under the direction of John L. Ridgway.

LOCATION

The fossil material in the collection from the Avawatz Mountains was found at California Institute of Technology Vertebrate Paleontology Locality No. 267. The locality lies on the southeasternmost flank of the Avawatz Mountains, ten miles by road northwesterly from the town of Silver Lake on the Tonopah and Tidewater Railroad (see fig. 2).

RÉSUMÉ OF GEOLOGIC OBSERVATIONS

In the geologic literature no reference has been made to the Tertiary sediments exposed at the southeastern end of the Avawatz Mountains. It is not within the scope of this paper to present a detailed account of the stratigraphical and structural relations of these sediments. However, a brief areal survey has brought out a few major facts.

Stratigraphy—As at many other localities in the Mohave Desert, the rocks of the southeastern portion of the Avawatz Mountains may be divided into three groups: (1) the basement complex of metamorphic and plutonic rocks, (2) the superjacent series of sedimentary rocks, and (3) the alluvium (Baker 1911, 1912; see Literature Cited at end of this paper). The basement complex outcrops only on the high central portions of the range. Lapping far up onto the range, and forming some of the high peaks and ridges, are the sedimentaries. Alluvium, which at present is being vigorously dissected, lies on the lower slopes across the beveled edges of the older sedimentaries. Away from the mountains, a younger alluvium is accumulating on the great fans and in the playas.

Basement complex of metamorphic and plutonic rocks—No attempt is made to unravel the complexities of the basement which comprises the core of

the Avawatz Mountains. However, judging from their outcrops, rock types occur which are potential sources for most of the boulders of the Tertiary conglomerates. These include quartzite, dolomite, marble, schist, gneiss, granite, and several types of darker igneous rocks, including one coarse-grained gabbro, which is composed to a large extent of hornblende. The basement consists of intimately associated small masses of these various rocks.

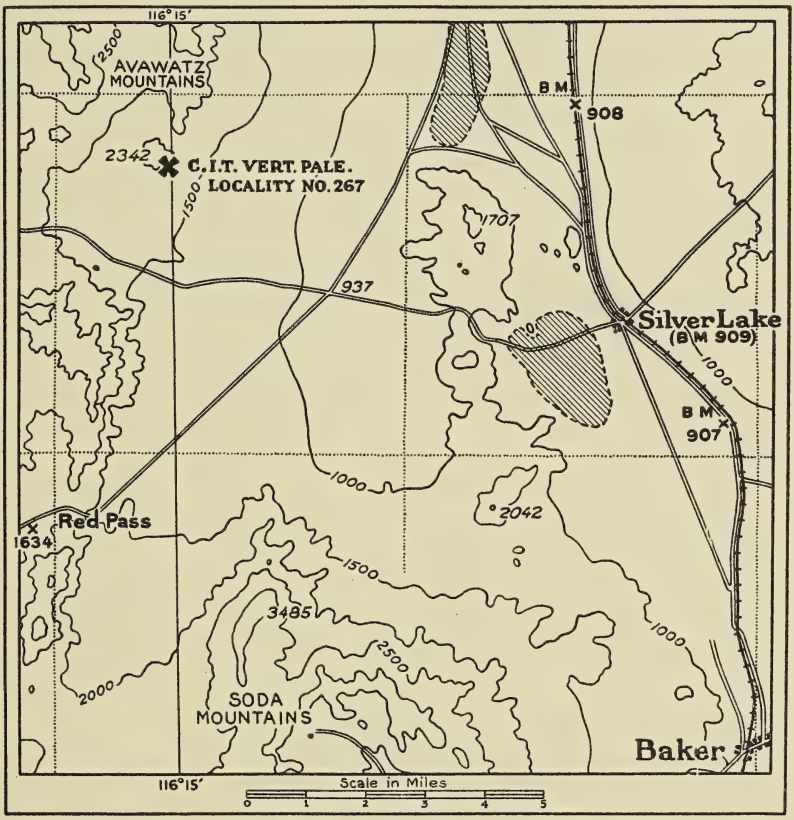

FIG. 2—Southeastern portion of the United States Geological Survey Avawatz Mountains Quadrangle showing the location of the California Institute vertebrate fossil locality in the Avawatz Mountains. Contour interval, 500 feet.

Overlying series of sedimentary rocks—Unfortunately any attempt to correlate stratigraphically the Tertiary sediments of the Avawatz Mountain area with those of other parts of the Mohave Desert region meets with considerable difficulty. Following the precedent established by J. C. Merriam in giving local formational names to the Barstow and Ricardo, the name Avawatz formation is proposed to include the Tertiary series which lies immediately to the south and west of the eastern end of the Avawatz Mountains. The lack of a map on an adequate scale prevented anything more than a most cursory survey of these Tertiary sediments. The forma-

tion may be roughly divided into four members: (1) a coarse conglomerate (fanglomerate), (2) green and brown clays (lake beds), (3) resistant breccia (atmoclastic breccia), and (4) arkosic sands and tuffs (fluviatile deposits).

The lower member, or fanglomerate, varies considerably in thickness, pinching out to the east and thickening to the west. Its thickness directly north of the fossil localities is well over 1000 feet, while to the west it appears to attain a thickness of several thousands of feet. The deposits are extremely coarse, and some of the boulders in this conglomeratic material measure five or six feet across. Sandy lenses and layers are almost completely absent except near the upper limit of the member where it grades into the overlying fine-grained sediments. From the nature of the rock types present it appears evident that the source of most of this material was the Avawatz basement complex. The character of the fanglomerate is heterogeneous for the most part. Several remarkably persistent layers exist, however, which for some 30 feet in thickness and several miles in extent along the outcrop consist throughout of one rock type. One of these layers, composed of light-colored granitic boulders and matrix, is remarkably well displayed, dipping off the mountain mass (see plate 1). There are a few other layers of individual rock types, some predominantly red while others are predominantly green. The degree of cementation of the material is not especially strong, except near the surface where caliche has been recently deposited.

Above a transition zone of intercalated clays, sands, and coarse to fine conglomerates, occurs the middle member of the Tertiary series. It consists dominantly of green, gray-green, and brown-green to brown fine sands and clays, the finer material making up the bulk of the deposits, while the more arenaceous zones occur for the most part near the lower and upper limits of the member. Ripple marks indicative of standing water were observed at certain levels. The origin of this member is one of deposition of sediments partly on flood plains and partly in playa lakes.

Conformably overlying the clay member occurs a series of coarse breccias, generally self-cementing and very resistant to erosion. The breccias consist of extremely angular blocky fragments, some of which are several feet across. Generally the lower part of the breccia is made up of a fine- to medium-grained, gray-green igneous rock, while gray dolomite or pure white limestone and marble form the upper part. A most remarkable feature is the constancy and uniformity of rock type composing these two separate parts of the breccia. Extremely little commingling of rock types occurs. The aggregate thickness of these breccias varies from place to place, ranging from perhaps a few tens to a few hundreds of feet. These breccias probably represent a fanglomeratic type of deposit approaching a talus breccia in character.

The uppermost member of the Tertiary formations has been considered in detail. Characterized by a predominance of arenaceous sediments over those of an argillaceous or tuffaceous character, this member is the only one

in which fossil vertebrate remains have been found. Very striking in appearance are several persistent layers, a few feet thick, of pure white volcanic ash, occurring in the lower part. These vary from fissile shales made up of paper-thin laminæ to massive beds so highly indurated as to break with conchoidal fracture. Other beds which have been employed as markers include several of punky gray volcanic ash, each a few feet in thickness. The upper part of the fluviatile deposits lenses gradually into a pebbly conglomerate and finally into a coarse conglomerate. Although some of this material was deposited in still water, as indicated by occasional layers showing oscillation ripple marks, the bulk of it was laid down under flood-plain conditions.

Quaternary—Resting with pronounced angular unconformity upon the Tertiary conglomerate is a coarse conglomerate which is believed to be Quaternary in age. Whether it is Pleistocene or Recent has not been ascertained. This younger conglomerate has itself been subjected to diastrophic movements which in one place at least have tilted the strata as much as 22°.

All of the formations discussed above are now being vigorously eroded, while out on the fans and playas alluviation is proceeding at a rapid rate.

Structure—An adequate structural picture of the Tertiary sediments of the Avawatz Mountains locality can be obtained only with detailed mapping. Unfortunately, in the absence of a sufficiently detailed topographical map, such work could not be carried out. In general terms, the dominant structure consists of a series of broadly to closely folded anticlines and synclines. The axes of the folds trend from N. 45° W. to N. 80° W., the former being nearer the mountain front and more nearly in parallel alignment with it. These structures plunge to the east and to the west from a region only a few miles west of the fossil localities.

In the area studied, at least three faults strike approximately east-west and have possibly vertical attitudes. Offset marker beds indicate that the movement along one of these breaks has been of the strike-slip type, the south side having moved eastward relatively to the north side a distance of several thousand feet. Minor faults with offsets of only a few feet are found in abundance throughout the Tertiary sediments. Probably the majority of these are subordinate breaks controlled by the formation of the major structures.

The structure of the Quaternary conglomerate demonstrates two interesting facts: First, in one place, where the conglomerate overlies with angular unconformity the limb of an anticline in the Tertiary rocks, the conglomerate has been tilted so as to dip as much as 22°, but preserves the strike of the underlying, more steeply dipping anticlinal limb. This indicates a continuation of folding along the same axes after a period of quiescence. Secondly, in the relatively undisturbed areas, the Quaternary conglomerate dips away from the main Avawatz range at angles varying from 4° to 8°. The channels of the streams now incising these beds dip at 1.5° or less.

STRATIGRAPHIC COLUMN OF THE FOSSILIFEROUS FLUVIATILE BEDS OF THE AVAWATZ FORMATION

Total thickness in feet	Thickness of beds in feet	
	60	Fine to coarse conglomerate resting with angular unconformity upon underlying beds.
976		.....Unconformity.....
	160	Sand layers and pebble conglomerates at base. Pebble lenses are thicker, more frequent in occurrence, and with larger pebbles in upper levels, finally becoming coarse conglomerate.
816		
	4	Punky gray ash.
812		
	76	Brownish-gray alternating coarse and fine fluviatiles, becoming sandy and gravelly toward top.
736		
	3	Punky gray ash. "Marker bed" in structure section.
733		
	150	Soft to hard gray sandy fluviatiles, occasional gravels, and brick-red pebbles. Mastodon 30 feet below "marker."
583		
	6	Punky gray ash, capped by hard sandstone. Highly fossiliferous. Remains of Antilocapridæ, Camelidæ, Equidæ, and Rodentia.
577		
	306	Fluviatiles, mostly greenish-gray sands with few green-gray clays. Some sands are light-gray micaceous arkoses. Fossils first appear here at about 450 feet above base of section.
271		
	64	Sandy fluviatiles, soft to hard, overlying a very thin white volcanic ash.
207		
	29	Greenish-gray punky shale.
178		
	2	Hard white volcanic ash.
176		
	70	Soft, poorly bedded, gray punky clays. Occasional sand layers. One bed of gray ash near base.
106		
	38	Gray ash passing upward into zone of brownish sandstone and gray ash.
68		
	1	Hard brown sandstone.
67		
	34	Light-gray ash, cross-bedded to finely bedded to laminated. Few sandy layers. Occasional layers containing rounded fragments of white volcanic ash.
33		
	27	Greenish-gray clays to gray sands, soft; show no bedding.
6		
	6	Greenish to yellowish-brown sands and gravel beds. Small pebbles of limestone.
0		
		Underlying resistant breccia (atmoclastic breccia), mostly limestone fragments, some gneisses.

Thus strong indication is given that there has been a relatively recent uplift in the area of, and contiguous to, the main body of the Avawatz Mountains.

Later geological history of the Avawatz Mountains—The geological history of the basement complex is a tangled skein which remains to be unraveled. Extremely rapid upwarping or upfaulting of the complex core marked the inception of recorded later geological history of the Avawatz Mountains. Though not strictly datable, this diastrophic movement probably commenced in later Tertiary time, perhaps toward the close of the upper Miocene. During this first uplift, many thousands of feet of very coarse fanglomeratic material were laid down on the flanks of the ancestral Avawatz Mountains. As the uplift slowed and eventually ceased, and as the mountains were eroded down and the intermontane basins were filled, the alluvium undergoing deposition became characteristically finer-grained. At the termination of this stage the topographic relief of the region was considerably reduced and extensive playa lakes lay in the intermontane basins.

Following this period of quiescence came a resurgence of diastrophic activity accompanied by vulcanism. The first swift uplift was marked by deposition of the resistant breccias. Over these breccias, perhaps after a short period of erosion, was laid down the succession of arkoses and tuffs, mostly fluviatile but partly lacustrine, in which were incorporated the scattered remains of many mammals. A gradual coarsening of the sediments, indicative of an increase in relief, brought the record of Tertiary sedimentation to a close in lower Pliocene time.

While all Tertiary diastrophism up to the close of lower Pliocene had been confined to simple successive relative uplifts of the mountain core, the tremendous forces coming into play in the uppermost Tertiary crushed and crumpled, as well as uplifted, the sediments which had been laid down earlier in the period. This Tertiary terrane, now structurally characterized by close folds, strike-slip faults, and perhaps thrust faults, was planed off by erosion to form a fairly even surface with few rugged hills of resistant breccia rising above the general level. On this surface accumulated a conglomerate, perhaps Pleistocene in age, occasionally aggregating several hundred feet in thickness. Renewed movement along old lines of folding locally tilted this conglomerate strongly. The primary dip of this conglomerate away from the mountain mass was considerably steepened by a general upwarping of the central portion of the Avawatz range.

Subsequent to this last uplift, the forces of erosion have been extremely active in dissecting the Tertiary terrane and developing the present youthful topography.

OCCURRENCE AND PRESERVATION OF MATERIAL

Fossil material has been recovered so far only from the uppermost member of the Tertiary Avawatz formation. All of the fossils found in place come from a stratigraphic zone about 250 feet thick immediately underlying

the gray tuff marker bed (see fig. 3, also stratigraphic column). Bone fragments are exceedingly common throughout this zone. No complete pieces were found. Though some of the teeth and bones show rounding and water wear, many appear remarkably fresh and unworn. The state of preservation is only fair. Checking has rendered many pieces very difficult

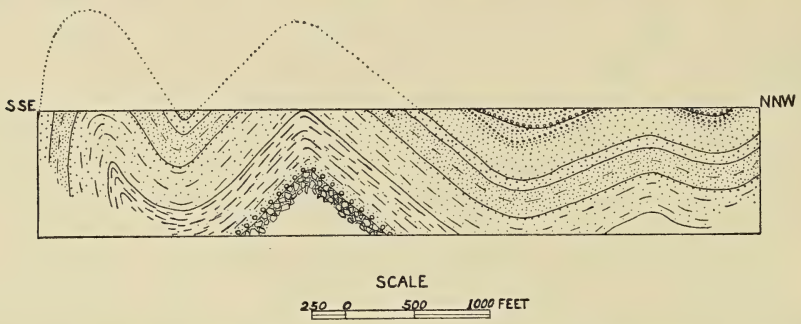

FIG. 3—Diagrammatic section taken at N. 20° W. through the east-west trending folds of the fossiliferous portion of the Avawatz formation. Marker bed indicated by projected dotted line.

to recover and prepare. This condition is believed to have been caused, in part at least, by the stresses set up during diastrophism. Preservation appears to have been brought about under flood-plain conditions, where vertebrate remains were stream-borne or at any rate widely scattered before burial.

ENVIRONMENT OF FAUNA

All the forms known at present to occur in the Avawatz fauna are typical plains dwellers. The vegetation of the region during the period of accumulation must have comprised grass and scrubby trees. Presence of the latter is indicated by occasional finds of petrified wood, the remains of shrub-like growths. To support such vegetation, the climate presumably was somewhat more humid than the present one. Perhaps, as J. C. Merriam suggests in regard to the environmental conditions of the Barstow and Ricardo faunas, the conditions prevailing at the time of existence of the Avawatz fauna resembled those now obtaining in the southern portion of the Great Valley of California.

COMPOSITION AND EVOLUTIONARY STAGE OF FAUNA

The small canid species recorded in the faunal list does not resemble generically any later Tertiary form described in the literature and hence is valueless as an indicator of the age of the fauna.

Presence of *Pseudælurus intrepidus* Leidy, a species based on a well-preserved lower jaw, discovered by Hayden in the sands of the Niobrara River (Leidy 1858, 1869), unfortunately gives no definite indication of age of the Avawatz fauna. Most of the recorded occurrences of *Pseudælurus* are assigned to the Miocene, including Barstow (Merriam 1919), Tonopah

(Stock 1934), Lower Snake Creek (Matthew 1918, 1924), and Niobrara River faunas (Leidy 1869). Two occurrences, however, from the lower Pliocene are referred to *Pseudælurus*, Esmeralda (Stirton 1936) and Valentine (Stirton and McGrew 1935).

An attempt to place the specimens which have been described in the literature in a faunal or evolutionary sequence is unsatisfactory, for some are derived from doubtful horizons while others are not figured, thus making comparisons difficult. A comparison with the Barstow fragment reveals nothing beyond general size agreement. When compared with the small form from Tonopah, the Avawatz specimen appears to be slightly more advanced, as suggested by a less well-developed heel on $M\bar{1}$ and smaller alveolus for $P\bar{2}$. However, these differences may have little significance.

Included in the collection from the Avawatz locality are a number of fragmentary rodent and lagomorph specimens. This assemblage consists chiefly of heteromyid rodents (pocket mice), of which there are present two or possibly three forms. A single specimen of a cricetine, *Peromyscus*, and several individuals of an extinct hare, *Hypolagus*, likewise occur (Wilson 1939).

The material has not afforded definite evidence with regard to age of the assemblage. An upper Miocene or lower Pliocene age is indicated, probably the latter.

In spite of the fact that mastodont remains have been reported from almost all of the Tertiary horizons having assemblages comparable to that of the Avawatz Mountains, only two formations have yielded lower jaw material sufficiently well preserved to be of value in making comparisons. The mastodont recorded as *Trilophodon ?* sp. from the Ricardo (Stock 1928) resembles the Avawatz form, although the mandible on which the former identification is based is very slightly larger than that of the latter in all its measurements. This difference in dimensions falls well within the limits of individual variation. The second occurrence is that of *T. simplicidens*, the type tooth of which was found in the lower Pliocene Bone Valley formation near Pierce, Florida. This horizon is regarded as the equivalent of the Rattlesnake by Simpson (Simpson 1933), while both Rattlesnake and Bone Valley are considered middle Pliocene by Stirton (Stirton 1936). Osborn suggests that the tooth "may be intrusive from older Miocene beds" (Osborn 1936). Since Osborn himself (Osborn 1923; 1936, p. 285) seemed doubtful as to the geologic age of *Trilophodon simplicidens*, a comparison of the Avawatz mastodont with this primitive form does not throw much light on the age of the Avawatz occurrence.

Remains of horses in the Avawatz collection include a poorly preserved upper molar, a set of lower incisors, and a few skeletal fragments, and they furnish little information of value in dating the fauna. The tooth has been assigned to the genus *Pliohippus* on the basis of the extremely strong curvature of crown and of the few features exhibited on the wearing surface. Though *Pliohippus* has been reported from a number of localities which

might be referred to the upper Miocene, in general these localities contain mixed faunas representing both upper Miocene and lower Pliocene. The exact stratigraphic position of *Pliohippus* is in doubt in these cases. For the present it is sufficient to say that if *Pliohippus* occurs in a fauna, the chances are excellent that the assemblage falls within the Pliocene. It is regrettable that the advanced stage of wear and poor preservation of the tooth do not permit a more satisfying determination of the relationships of the Avawatz *Pliohippus*.

Two representatives of the Camelidæ are found in the Avawatz fauna. The larger of these is about twice the size of the smaller. Similar variation in size among Tertiary camels appears to be of common occurrence in faunas related in age to the Avawatz. For lack of material, the larger camel cannot be identified, even generically. The smaller form, however, has been referred specifically to *Procamelus coartatus* Stirton, which was described from Fish Lake Valley.

Pending publication by Frick of the stratigraphic and faunal relationships of *Merycodus cerroensis* (Frick) from Round Mountain, New Mexico, the Avawatz antilocaprid has been referred tentatively to Frick's species.

With regard to the position of *Merycodus* cf. *cerroensis* (Frick) in the genus, several definite statements can be made. The material from the Avawatz, like that of Frick's type, represents a specialized form among merycodonts. This is clearly demonstrated by the extreme reduction of the premolar series with respect to the molars and by the remarkable elongation of the post-symphyseal diastema. Frick refers his Round Mountain material to the "Uppermost Late Tertiary," which means presumably at least middle Pliocene. Such a determination might appear logical did we not feel certain that *Ilingoceros* and particularly *Sphenophalos* had established themselves by that time as the dominant antilocaprids (Merriam, Stock, and Moody 1925). Furthermore, the merycodont tentatively referred to *M. cerroensis* may be an unusually advanced type, in this regard standing in contrast to the more primitive aspect of the remainder of the fauna. With the discovery of more material in the Ricardo such an assumption may prove unnecessary, for in at least one Ricardo specimen (U.C. No. 22450, Merriam 1919, fig. 243), in which molars and premolars are preserved in the same ramal fragment, there exists a strong suggestion of premolar reduction comparable to that found in *M.* cf. *cerroensis* from the Avawatz and in *M. cerroensis* from Round Mountain, New Mexico. Hence, though the structure of the horn core remains distinct, the dentary of the Ricardo *Merycodus* with its slightly more hypsodont molars and slightly less reduced premolars may, in stage of development, be roughly analogous to the Avawatz form.

RELATIONSHIPS OF FAUNA

Great Basin—In the Tertiary deposits of the Great Basin region of southeastern California and western Nevada occur several faunas whose con-

stituencies resemble that of the Avawatz. However, greatest resemblance appears to exist between the latter and assemblages that are either latest Miocene or earliest Pliocene in age. In the Barstow fauna (Merriam 1919) no forms are similar to those found in the Avawatz. *Merycodus necatus* Leidy from the Barstow exhibits characters which are decidedly more primitive than those of *M.* cf. *cerroensis* (Frick). Greater similarity, on the other hand, exists between the faunas from the Avawatz and Ricardo deposit (Merriam 1919, Matthew 1924, Stock and Furlong 1926, Matthew and Stirton 1930, Stirton and Vander Hoof 1933). *Trilophodon* cf. *simplicidens* Osborn appears to be close to *Trilophodon ?*, sp. (Stock 1928). *Pliohippus ?*, sp. may be related to one of the Ricardo pliohippines. *Procamelus coartatus* from the Avawatz approaches the form *Procamelus*, sp. b described by Merriam from the Ricardo. The merycodonts, although not of the same species, represent approximately a similar stage of advancement. *Pseudælurus ?* occurs in the Fish Lake Valley fauna (Stirton 1929, 1932, 1936), but for lack of adequate material this species cannot be compared directly with that of the Avawatz. *Pliohippus* cf. *leidyanus* and *Procamelus coartatus* occurring in the Fish Lake Valley fauna may well have been contemporaries of the Avawatz forms.

Pacific Coast—Tertiary assemblages from the Pacific Coast Province do not offer any close comparisons with the Avawatz fauna. The Chanac fauna which has been described in the literature (Merriam 1916*b*, Hoots 1930, Stock 1935) is very incompletely known except for the Equidæ. Some undescribed material in the collections of the California Institute of Technology indicates that although the Antilocapridæ from the Chanac are probably less advanced than those of the Avawatz, the Proboscidea and Equidæ may be more advanced. The Orinda-Siesta fauna (Merriam 1913, 1917, Stock 1921, Stirton 1935), for lack of corresponding material, cannot be compared with the Avawatz. The fauna from Mint Canyon (Maxson 1930, Stirton 1933) may represent more than one stage, while that from the Cuyama (Gazin 1930) does not furnish an adequate basis for comparison.

Great Plains—In the Great Plains Province there are again several mixed faunas with which comparison is at present difficult, if not meaningless. The Santa Fe of New Mexico certainly represents more than one faunal stage (Frick 1933, p. 549), and this is true also for the Upper Snake Creek of Nebraska. The fauna formerly termed Valentine has been divided into three parts by Stirton and McGrew (1935). The middle of these, the Burge, is characterized by an assemblage which may approximate in time that from the Avawatz. In the latest available list of mammals from the Burge (McGrew and Meade 1938), the comparable forms have been determined generically but not specifically; hence critical comparison is not yet possible. The Madison Valley fauna of Montana (Douglass 1900) appears definitely more primitive than the Avawatz. The Clarendon fauna of Texas (Cope 1893) contains no forms comparable to those from the California locality.

FAUNAL LISTS

Ricardo	Avawatz	Fish Lake Valley	Barstow
		Insectivora	
		Meterix latidens Hall	
		Metechinus nevadensis Matthew	
		Chiroptera	
		Mystipterus vespertilio Hall	
Carnivora	Carnivora	Carnivora	Carnivora
Canid, small near Canis ? vafer Leidy	Canid, indet.		Canid (Canis ?), sp. small
Ælurodon ? aphobus Merriam		Ælurodon haydeni (Leidy)	Tephrocyon, near temerarius (Leidy)
Ælurodon ?, n. sp. a			Ælurodon, near wheelerianus Cope
Ælurodon ?, n. sp. b			Ælurodon, Dinocyon, or Amphicyon, sp.
Ælurodon or Tephrocyon, sp. c			
Ælurodon or Tephrocyon, sp. d			
Osteoborus ricardoensis Stirton and Vander Hoof			
Hadrocyon mohavensis Stock and Furlong			Machærodont, sp. a
Mustela ? buwaldi Merriam			Machærodont, sp. b
Ischyrosmilus osborni Merriam			Machærodont, sp. c
Felid, large			Felid ?, indet.
Felid, small, not Ischyrosmilus	Pseudælurus intrepidus Leidy	Pseudælurus ?	Pseudælurus, sp.
Rodentia	Rodentia	Rodentia	Rodentia
		Eucastor tortus Leidy	
		Mylagaulus, sp.	
		Entoptychus ?	
	Perognathoides cf. tertius (Hall)	Perognathoides quartus (Hall)	
	Perognathoides ?, sp. undet.	Perognathoides tertius (Hall)	
	Dipodomyine ?, n. g. et sp.	Macrognathomys nanus Hall	
	Peromyscus dentalis Hall	Peromyscus dentalis Hall	
Lagomorpha	Lagomorpha	Lagomorpha	Lagomorpha
Lepus ?, sp.	Hypolagus, sp.	Hypolagus cf. vetus L. Kellogg	Lepus ?, sp.
		Sylvilagus ?	
Proboscidea	Proboscidea	Proboscidea	Proboscidea
Trilophodon ?, sp.	Trilophodon cf. simplicidens Osborn		
Tetrabelodon ?, sp.			Tetrabelodon ?, sp.

(*Continued on next page*)

FAUNAL LISTS—*Continued*

Ricardo	Avawatz	Fish Lake Valley	Barstow
Perissodactyla	Perissodactyla	Perissodactyla	Perissodactyla
Aphelops, sp.			
Peraceras ?, sp.			
Hipparion mohavense Merriam			
		Hypohippus, near nevadensis Merriam	Hypohippus, near affinis (Leidy)
Hipparion mohavense callodonte Merriam		Neohipparion cf. occidentale Leidy	Parahippus ? mourningi Merriam
Hipparion, sp. a			Merychippus (Protohippus) intermontanus Merriam
Hipparion, sp. b		Pliohippus cf. leidyanus Osborn	Merychippus calamarius stylodontus Merriam
Pliohippus tantalus Merriam	Pliohippus ?, sp.		Merychippus sumani Merriam
Pliohippus fairbanksi Merriam			Protohippus ? or Pliohippus ?, sp.
Pliohippus, sp. near mirabilis (Leidy)			
Artiodactyla	Artiodactyla	Artiodactyla	Artiodactyla
		Tayassuidæ	Tayassuidæ
		Prosthennops cf. crassigenis Gidley	Prosthennops ?, sp.
Merycoidodontidæ			Merycoidodontidæ
Metoredon californicus (Merriam)			Merycochœrus buwaldi Merriam
Camelidæ	Camelidæ	Camelidæ	Camelidæ
Procamelus, sp. a		Procamelus gracilis Leidy	Procamelus, sp. a
Procamelus, sp. b	Procamelus coartatus Stirton	Procamelus coartatus Stirton	Procamelus, sp. b
Pliauchenia, sp.	Camelid, sp. large	Procamelus cf. robustus Leidy	Pliauchenia, sp.
Alticamelus ?, sp.		Alticamelus cf. priscus Matthew	Alticamelus ?, sp.
			Cervidæ
			Dromomeryx or Cervus ?, sp.
Antilocapridæ	Antilocapridæ	Antilocapridæ	Antilocapridæ
Merycodus, near necatus Leidy	Merycodus cf. cerroensis (Frick)	cf. Merycodus	Ramoceras (Paramoceras) brevicornis Frick
Merycodus furlongi (Frick)			Ramoceras (Merriamoceras) coronatus (Merriam)
			Merycodus (Paracosoryx) alticornis (Frick)
			Meryceros joraki Frick

Conclusion—Although the fragmentary nature of the material and an almost complete absence of equine remains make anything more than a suggestion of chronologic arrangement impossible, all available evidence points to a position of the Avawatz fauna in time close to that of the Ricardo and Fish Lake Valley. The Avawatz is perhaps slightly pre-Ricardo in age and approximately the equivalent of the Fish Lake Valley.

RELATIONSHIP OF THE AVAWATZ FAUNA TO MIOCENE-PLIOCENE VERTEBRATE HORIZONS OF WESTERN NORTH AMERICA

AGE	CALIFORNIA		NEVADA	OREGON	NEBRASKA
	PACIFIC COAST	MOHAVE			
Middle Pliocene			Thousand Creek	Rattlesnake	
Lower Pliocene	Chanac	Ricardo Avawatz	Fish Lake Valley		Burge
Upper Miocene		Barstow			Valentine

DESCRIPTION OF FAUNA

CARNIVORA

CANIDÆ

Canid, indet.

A right maxillary fragment (C.I.T. No. 2308, plate 2, figs. 2 and 2*a*) possessing the premolar tooth-row but lacking the molars, canine, and incisors, belongs to a canid species approximating the fox (*Vulpes*) in size.

P1 is a peg-like, single-rooted tooth with rounded anterior ridge, convex in profile. The ridge running from apex to posterior border, on the other hand, is more sharply defined and has a concave profile. Near the cingulum this concavity is more pronounced, so that a slight but definite shelf is formed. Hence, an angular break in tooth profile occurs between the posterior edge of the crown and the posterior edge of the root of the tooth.

P2 is slightly injured anteriorly. This tooth is double-rooted and presents a triangular lateral aspect. The anterior ridge is almost straight from tip to border of crown, while the posterior border is concave.

P3 is considerably larger than P2 and possesses a slightly concave anterior ridge and a strongly concave posterior ridge. No extra tubercles or cusps subsidiary to the main cusp are present.

In P4 the principal cusp is the acutely pointed paracone, while the metacone forms a long shearing blade. A small well-developed protocone is present, but the position of this cusp is not so far anterior as in other canids. The tooth further differs from that of other canids in being larger, more robust, and not so compressed laterally. The blade-like edges are not so sharp and the interconal notches not so deep in No. 2308 as in P4 of Recent canids.

Relationships—The form and proportions of the specimen from the Avawatz resemble fairly closely those of *Vulpes vafer* (Leidy). However, in the literature the upper dentition of this species is neither discussed nor figured. Hence, it seems undesirable to refer the form to the species *V. vafer*.

Since all the teeth of the premolar series in No. 2308 show distinctive differences from corresponding teeth in *Vulpes macrotis*, it is probably safe to say that the two forms do not belong to the same genus.

Measurements (in millimeters)

	No. 2308 C.I.T.
P1–P4, total length	32.5
P1, anteroposterior diameter	3.2
P1, transverse diameter	2.0
P2, anteroposterior diameter	ca. 5.7
P2, transverse diameter	2.0
P3, anteroposterior diameter	6.5
P3, transverse diameter	2.3
P4, anteroposterior diameter	11.0
P4, transverse diameter	5.0

FELIDÆ

Pseudælurus intrepidus Leidy

A poorly preserved left ramus is the only diagnostic felid material from the Avawatz (C.I.T. No. 2309, plate 2, figs. 1 and 1*a*). The lower edge

and posterior portion of the ramus are missing. $P\overline{3}$, $P\overline{4}$, and $M\overline{1}$ remain, but are badly shattered. A small calcaneum and astragalus in the collection are perhaps of this species.

In size the ramus resembles *Pseudælurus intrepidus* Leidy (1869) much more closely than it does the smaller form *Pseudælurus marshi* Thorpe (1922). The anterior mental foramen is large and lies below $P\overline{2}$. Behind this opening are two small foramina, which lie beneath the posterior root of $P\overline{3}$. The masseteric fossa is deep, with anterior end reaching forward to a point beneath the posterior root of $M\overline{1}$.

The incisors are lacking. The canine is likewise gone, but judging from that portion of its alveolus which remains this tooth was of large size. Behind a short diastema, there appears to be a small cup-like depression on the alveolar border of the ramus which may represent a socket for a small single-rooted $P\overline{2}$.

$P\overline{3}$ is a large double-rooted tooth. The crown consists of a large central cusp with small anterior and posterior cuspules. Of these, the anterior is the least developed. This tooth, along with those which follow, is set slightly diagonally to the fore-and-aft axis of the jaw.

$P\overline{4}$ is so placed that its anterior end lies immediately inside the posterior end of $P\overline{3}$, and the teeth overlap about 2 mm. It is slightly larger than $P\overline{3}$, double-rooted, and with anterior and posterior cusps larger in proportion to the main cusp than are those of $P\overline{3}$. Posteriorly there is, in addition, a fourth very low heel-like cusp, the talonid.

$M\overline{1}$ overlaps $P\overline{4}$ on the inside by more than 3 mm. and has a position decidedly diagonal with reference to the long axis of the ramus. The acutely pointed paraconid is separated by a broad deep notch from the protoconid or main cusp. A very small cusp on the posterior ridge of the tooth is all that is left of the metaconid. The talonid or heel, while not so much reduced as the metaconid, is weakly developed. There is no indication of a second molar.

Relationships—In structural characters the species from the Avawatz Mountains resembles most closely Leidy's *Pseudælurus intrepidus*. The differences between the Californian form and the type of *P. intrepidus* are the relatively advanced position of the anterior edge of the masseteric fossa in the former and the relatively greater diastema between $\overline{C}$ and $P\overline{3}$ in the latter.

Age—Most of the recorded occurrences of *Pseudælurus* are assigned to the Miocene, including those from Barstow, Tonopah, and Lower Snake

Comparative measurements (in millimeters)

	Pseudælurus intrepidus Avawatz No. 2309 C.I.T.	Nio-brara	No. 772 C.I.T.	Tonopah No. 1233 C.I.T.	No. 1234 C.I.T.	*P. marshi* Thorpe Valentine No. 12865 Y.P.M.
Depth of jaw at posterior end of $M\overline{1}$	ca. 22.5	22.5	ca. 21.7	22.5		21.7
Thickness of jaw below $M\overline{1}$	11.0		9.5	9.5		
$P\overline{3}$–$M\overline{1}$, total length	42.7	43.6	42.5	38.2		36.0
Diastema between $\overline{C}$ and $P\overline{3}$	10.0	14.8		10.0		8.6
$P\overline{3}$, anteroposterior diameter	11.0	11.4	10.5	10.3		9.5
$P\overline{3}$, transverse diameter	5.0	5.2	5.3	4.6		4.8
$P\overline{4}$, anteroposterior diameter	15.5	14.8	14.3	13.0	12.5	12.5
$P\overline{4}$, transverse diameter	6.6	7.2	6.8	5.8	6.0	6.0
$M\overline{1}$, anteroposterior diameter	19.6	19.6	ca. 18.9	15.3	16.5	16.0
$M\overline{1}$, transverse diameter	ca. 7.8	7.9	ca. 7.0	6.6	6.9	7.5

Creek. The genotype described by Gervais came from Sansan (Miocene). Leidy, however, records *Pseudælurus* from his Bed F or Pliocene and upward. Nevertheless, the occurrence of *Pseudælurus* in the Avawatz fauna suggests a Miocene rather than a Pliocene age.

PROBOSCIDEA

Trilophodon cf. simplicidens Osborn

An incomplete and badly fractured mandible (C.I.T. No. 1984, plate 2, fig. 3) bearing three poorly preserved molar teeth (right $M\bar{2}$ and $M\bar{3}$; left $M\bar{2}$) represents available proboscidean material from the Avawatz Mountains. Although the posterior portion of the symphysis remains, the anterior end is lacking. The preserved portion of the symphyseal area suggests considerable elongation and slight downward deflection of the mandible in this region. The right ramus extends posteriorly only to the heel of $M\bar{3}$ and the left ramus is broken or eroded off at the middle of $M\bar{3}$. Enamel thickness measures approximately 7 mm.

Both second lower molars show considerable wear. They retain enough of their original form, however, to demonstrate the fundamental pattern of three main ridge crests. Unfortunately the state of wear has removed all evidence of the presence or absence of central conules in a younger stage.

In the right $M\bar{3}$ the internal cone of the tetartolophid and the entire heel are missing. All of the main cones are broken off in the anterior portion of this tooth. The ridge crest formula was probably $4\frac{1}{2}$. Intercrestal conules are present and it is doubtful whether these would develop a trefoil pattern with further wear. The tooth as a whole is very slender and possesses a low breadth-length ratio.

The specimen is distinctive by reason of its small size and simplicity of dental pattern. These characters are apparent in but one of all the American trilophodonts, namely *Trilophodon simplicidens* Osborn (1923, 1936) from the lower Pliocene Bone Valley of Florida. The Avawatz form resembles in appearance, but is slightly smaller than, the specimen from the Ricardo referred by Stock to *Trilophodon* (?), sp. (Stock 1928).

Comparative measurements (in millimeters)

	T. cf. *simplicidens* Avawatz No. 1984 C.I.T. (approximate only)	*T. simplicidens* Bone Valley No. 1907 Amer. Mus.
Transverse diameter across protolophid	53	
Transverse diameter across metalophid	57	60
Transverse diameter across tritolophid	58	63
Transverse diameter across tetartolophid		55
Height of tetartolophid	37	35

PERISSODACTYLA

EQUIDÆ

Horses are conspicuous because of their scant representation in the Avawatz fauna. Among the fragments found are a set of lower incisors and canines (C.I.T. No. 2313, plate 2, fig. 4) and a distal end of a tibia for which no definite generic determination seems possible. A much worn upper cheek-tooth is described below (C.I.T. No. 2312, plate 2, fig. 5).

Pliohippus ?, sp.

The tooth appears to be a first molar. The plications in an otherwise simple crown-pattern are a pli protoconule and a pli caballin. The fossettes appear simple and large. The large, flattened-oval protocone, though only partially preserved, is obviously united to the protoloph. Strong curvature characterizes the worn crown. The size and curvature of the crown as well as the simple type of enamel pattern are strongly suggestive of the genus *Pliohippus*.

Measurements (in millimeters)

M1, anteroposterior diameter	24.5
M1, transverse diameter	ca. 23.0
M1, crown height (measured along mesostyle)	33.4

ARTIODACTYLA

CAMELIDÆ

Camelid remains occur in abundance but, unfortunately, most of the material is so fragmentary as to be of little diagnostic value. The collection includes fossil camelid remains which fall into two distinct size groups.

Procamelus coartatus Stirton

The material referred to this species belongs to several individuals. At any rate, no two fragments can be assigned to a single individual with any degree of certainty. The material consists of a fairly well-preserved palate of an adult, containing the tooth-row complete from P2 to M3 (C.I.T. No. 1989); a partially preserved palate of a young specimen bearing Dm3, Dm4, and M1 (C.I.T. No. 2315); several ramal fragments, none of which carries the complete mandibular dentition; lower teeth including P2 (roots only), P3, P4, M1, M2, M3, and Dm4; several ramal symphyses; distal end of humerus; proximal end of radius and distal end of radius-ulna; proximal and distal ends of femur; distal end of tibia; distal end of a cannon bone; termini of a proximal phalanx; two median phalanges.

Although the material from the Avawatz averages about one-tenth smaller in every dimension, in all other respects it approximates closely Stirton's type specimen from the Fish Lake Valley beds, Nevada (Stirton 1929).

Stirton states [1] that specimen U.C. No. 29612, provisionally assigned by him to *Procamelus gracilis* Leidy, may also be referable to the species *P. coartatus*. The difficulty in arriving at a definite determination lies in the fact that, in making a restoration of the palate, the proper width of the roof of the mouth between the second upper premolars cannot be ascertained with accuracy. If in the restoration the anterior portions of the maxillaries were brought somewhat closer together, the palate would appear remarkably similar to that of the typical *P. coartatus*. In the following comparison this specimen (U.C. No. 29612) will be regarded as of the species *P. coartatus*.

The palate from the Avawatz (C.I.T. No. 1989, plate 3, fig. 1) bears a marked resemblance to that in the University of California collections from Fish Lake Valley (U.C. No. 29608). Especially striking is the extreme constriction of the palate just anterior to P2 in both specimens. No other species of the genus *Procamelus* exhibits such extreme "pinching in" of the

[1] Personal communication.

anterior portion of the palate. A palatine foramen lies median to the posterior lobe of $M\underline{1}$.

The well-worn upper premolar teeth of the Avawatz form seem to be of proportions similar to those of specimens U.C. No. 29608 and U.C. No. 29612, although in the case of the latter the teeth appear to be slightly narrower in relation to their length. Part if not all of the relatively great breadth which is so striking in the illustrations of C.I.T. No. 1989 may be ascribed to an advanced stage of wear of the molar series.

In $M\underline{1}$ of U.C. No. 29612 there is present a very prominent accessory lingual cusp. $M\underline{1}$ of C.I.T. No. 1989 has been worn down to such an extent that if a comparable cusp ever was present it has now been entirely obliterated. However, in a maxillary fragment (C.I.T. No. 2341) in the Avawatz collection an unworn $M\underline{1}$ does not possess an accessory lingual cusp. The significance of this cusp in the U.C. specimen is uncertain.

Knowledge of the lower dentition of the species from the Avawatz must be obtained from fragmentary evidence. No evidence is available concerning the general proportions of the ramus. Individual teeth or short series of teeth on scattered mandibular fragments furnish some information on the lower dentition.

One fragment bears very well-worn teeth, $P\bar{2}$ (roots only), $P\bar{3}$, $P\bar{4}$, $M\bar{1}$, and $M\bar{2}$ (badly shattered roots only) (C.I.T. No. 2316, plate 3, fig. 2). Another fragment carries $M\bar{2}$ (moderately worn) (C.I.T. No. 2317, plate 3, fig. 5), while $M\bar{2}$ and $M\bar{3}$ (well worn) are present on a third fragment (C.I.T. No. 2318, plate 3, fig. 3). $Dm\bar{4}$, well preserved and only moderately worn, occurs in another fragment (C.I.T. No. 2319, plate 3, fig. 4). This tooth is almost identical with a long narrow Dm4 from the Ricardo (Merriam 1919, fig. 219).

Because of difference in stage of wear, the dental patterns of the lower teeth in the collections of the California Institute cannot be compared critically with those occurring in U.C. No. 19820 from the Cedar Mountain beds of Stewart Valley. In general, however, they appear to be accordant. The material from the Avawatz is not so large and robust. The premolars of the Avawatz form appear to be somewhat reduced, but perhaps much of this apparent reduction is to be ascribed to the advanced stage of wear which these teeth display.

Although the mandibular symphyses in the collection show some variation in size, they are all characterized by a strong constriction of the lower side of the symphysis slightly anterior to the mental foramen. The halves of the mandible in an adult individual are firmly fused along the symphyseal plane, leaving no trace of suture. One specimen bears the shattered roots of three incisors, one canine immediately posterior to the incisors, and $P\bar{1}$, double-rooted, located directly above the mental foramen (C.I.T. No. 2320). In another specimen of a young individual the symphyseal suture is not yet obliterated. In this fragment the canines are small and $P\bar{1}$ has not yet erupted (C.I.T. No. 2321, plate 4, fig. 3).

With minor variations the limb bones of *P. coartatus* from the Avawatz fall within the limits of individual variation of the Recent *Lama huanachus* (see plate 4).

Comparative measurements (in millimeters)

	Avawatz No. 1989 C.I.T.	Fish Lake Valley No. 29608 U.C.
Palate:		
Inside width at narrowest point (measured on crests of alveolar ridge)	7	8
Distance between inner edges of fourth premolars	22	ca. 29

Upper dentition:	Avawatz C.I.T. No. 1989	Fish Lake Valley U.C. No. 29608	Fish Lake Valley U.C. No. 29612
P2–M3, total length	95.8		106.8
P2, anteroposterior diameter	8.0	8.7	8.7
P2, transverse diameter	5.0	4.5	4.5
P3, anteroposterior diameter	11.2	12.4	11.8
P3, transverse diameter	6.8	6.6	6.0
P4, anteroposterior diameter	11.4	11.5	12.0
P4, transverse diameter	9.4	9.7	9.0
M1, anteroposterior diameter	15.3 (base)	21.0 (crown)	17.2 (base) / 21.6 (crown)
M1, transverse diameter	15.5 (base)	14.2 (crown)	16.9 (base) / 14.9 (crown)
M2, anteroposterior diameter	25.2	24 ?	28.4
M2, transverse diameter	17.8	19 ?	16.4
M2, crown height	12.0 (worn)		28.0 (unworn)
M3, anteroposterior diameter	29.8		27.8
M3, transverse diameter	17.7		16.4
M3, crown height	16.0 (worn)		21.0 (unworn)

Mandible:	Avawatz No. 2321 C.I.T.	Fish Lake Valley No. 19820 U.C.
Narrowest width of symphysis	20.0	30.4
Height of symphysis at narrowest width	15.8	27.2

Lower dentition:	No. 2316	
P2–M1, total length	40.0	46.9
P2, anteroposterior diameter	5.2 base	6.0 base
P2, transverse diameter	2.8	3.6
P3, anteroposterior diameter	8.4	11.0
P3, transverse diameter	4.4	5.0
P4, anteroposterior diameter	11.2	13.9
P4, transverse diameter	5.5	6.4
M1, anteroposterior diameter	15.4	15.8
M1, transverse diameter	10.2	10.6
	No. 2317	
M2, anteroposterior diameter	22.5 base	22.0 base
M2, transverse diameter of anterior lobe	11.0	12.5
M2, transverse diameter of posterior lobe	13.8	16.8
	No. 2318	
M3, anteroposterior diameter	34.0	40.0 base
M3, transverse diameter	?	
	No. 2319	
Dm4, anteroposterior diameter	25.5	
Dm4, transverse diameter of anterior lobe	5.7	
Dm4, transverse diameter of posterior lobe	7.2	
Dm4, transverse diameter of medial lobe	6.8	

Camelid, indet.

A portion of a large mandibular symphysis, many vertebræ, the iliac portion of an innominate bone, distal end of a tibia (C.I.T. No. 2336, plate 4, fig. 7), an astragalus (L.A. Mus. Coll.), distal end of a metapodial, one complete (C.I.T. No. 2340, plate 4, fig. 8) and one incomplete proximal phalanx indicate the presence of a large camelid almost exactly twice the size (linear) of *P. coartatus*. The fragmentary state of this material and the fact that the material has little diagnostic value preclude the possibility of making a satisfactory generic determination.

ANTILOCAPRIDÆ

Merycodus cf. cerroensis (Frick)

Merycodont remains are the most abundant fossil specimens found in the Tertiary beds of the Avawatz Mountains. While fragments of horn cores, parts of rami, and loose teeth abound, complete and well-preserved specimens are rare. Small bones and terminations of larger elements of the appendicular skeleton are well represented in the collection. However, one of the long limb bones was preserved intact. That some of the individuals are quite young is attested to by the several rami which bear the deciduous fourth premolar and by the terminal epiphyses of the phalanges that are often free from the main shafts. The unworn state of the crowns of teeth indicates that none of the rami or maxillæ belonged to individuals older than young adults. In no case was a dental series found in definite association with horn cores. Like the teeth and phalanges, however, the horn cores probably represent mostly sub-mature to young adult individuals.

Typical specimens of horn cores have a long beam which branches into two tines of subequal length and longer than the beam. There is a tendency to form a wide flare where the tines branch off, and the latter tend to bend inward at the tips (C.I.T. Nos. 1992, 1994, 1993, and 1991, plate 5, figs. *a*, *b*, *c*, and *d*; also C.I.T. No. 1990, plate 6, figs. 1 and 1*a*). The base of each horn core stands directly over the posterior portion of the orbit. The pedicle of the core rises perpendicularly on the frontlet, but it curves anteriorly and laterally toward the region of bifurcation. The two tines diverge at approximately 90°; one is directed anteriorly while the other projects laterally. In both tines a reverse curve occurs in the last 45 mm., so that the tips point upward. The anterior tine (120 mm.) is slightly longer than the lateral tine (110 mm.). When the part of the frontlet between and posterior to the horn cores is held horizontally, a plane passed through the lower part of a pair of tines makes an angle of less than 45° with the horizontal. Also such a plane lies at an angle of approximately 60° to the median plane of symmetry of the skull. This latter figure is especially significant in that no specimens yet described show such a high degree of rotation of the tines from the usual fore-and-aft position. The surface of the horn core is grooved by shallow anastomosing nutrient canals. All parts of the horn core, except in the proximity of the spread-out bifurcation, are round-oval to circular in cross-section.

Of the horn cores figured in the literature, the specimens at hand resemble most closely those from Ricardo and Barstow, California, identified only generically as *Merycodus* sp. (Furlong 1927, plate 28, U.C. Nos. 27242, 27243, and 27249). Other figures which bear marked similarity in structure and proportions to the horn-core material from the Avawatz Mountains are those of *Cosoryx* (*Subcosoryx*) *cerroensis* Frick from Round Mountain Quarry, New Mexico (Frick 1937, fig. 38, F:A.M. Nos. 33105, 33108, 33113H, 33114, 33116). This species is characterized by Frick (Frick 1937, pp. 336 and 338) as having a variable prong-to-beam ratio, but always "with tendency to rather wide flare and bending of tips." Also, "several cranial saddles indicate the presence of individuals in which the horn-cores are peculiarly rotated antero-inwardly." A horn core from the Cedar Mountain beds of Ione Valley, Nevada, identified by Merriam as *Merycodus furcatus* (Leidy) also exhibits the form of the specimens from the Avawatz Mountains (Merriam 1916*a*, fig. 44, U.C. No. 21492).

Other horn cores described in the literature and identified as *M. necatus*

or *M. furcatus* are not proportioned and curved as are the specimens from the Avawatz.

Only one beam out of the twenty in the collection appears to be without a burr. It is significant that while all other cores are relatively robust, having maximum diameters from 17 to 21 mm. below the burr, the burrless beam is delicate and has a maximum diameter of only 13.5 mm. The latter unquestionably belonged to a young individual. Most of the burrs slope more or less steeply downward from a high anterior to a low posterior position.

In only one specimen is a frontlet preserved. The loosely knit sutures point to the youth of this individual. The frontoparietal suture crosses the skull rather far back (10.4 mm.) behind a line drawn tangent to the posterior side of the horn cores. This is not so far back, however, as in some skulls of *Merycodus* from other localities. The width measured between the lateral sides of the horn cores is 63 mm., while the width between the medial sides is only 32 mm. The frontals dome up between the horn cores along the median line of the skull. Immediately anterior to this doming the frontals drop away sharply to form a shallow depression. The supraorbital foramina are situated in deep hollows, anterointernal to the bases of the horn cores. Although no orbits have been completely preserved, they appear to be characteristically large and strongly projecting.

Besides numerous loose teeth, three or four fragmentary maxillary dentitions and more than a dozen parts of rami have been preserved. A single right maxilla and a single left ramus are the only specimens which bear complete tooth-rows.

Of the upper molars, M2 and M3 are clearly long-crowned teeth. M1 still retains roots which are approximately one-third the length from root-tip to wearing surface. P3 and P4 are definitely hypsodont, but by no means so long-crowned as are the corresponding teeth in *Antilocapra americana*. P2 shows only slight tendency toward hypsodonty.

Present among the Avawatz material is a portion of a maxillary tooth-row containing Dm4, M1, and a partially erupted M2 (C.I.T. No. 1996). Dm4, which has not yet been figured or described in the literature, is a short-crowned tooth with two-lobed crown-pattern, in contrast to the single crescent form of P4. The posterior lobe of Dm4 resembles a molar crescentic lobe, but is slightly more compressed anteroposteriorly and does not have such prominent styles as are found in a molar. The anterior lobe is asymmetric. Its crescentic pillar is strongly developed and a deep valley, reaching to the cingulum, lies between this crescentic pillar and the anterior very weak parastyle. This arrangement of a weak parastyle, a strong anterior crescentic pillar, and a still stronger posterior lobe gives the buccal surface of the tooth crown a step-like appearance.

The ratio of length of premolar tooth-row to length of molar tooth-row indicates an amount of shortening of the premolar series greater than that found in most merycodonts. Furthermore, the entire tooth-row appears to be more compressed laterally than is common in other merycodonts. Except for this general lateral compression, the crown-pattern of the upper dentition is in complete harmony with the pattern observed in all merycodonts and antilocaprids (Frick's *Antilocapridæ*). On the external side the crescentic pillars are merely gently rounded ridges. The styles, in contrast, are sharply marked ridges.

The lack of depth in the horizontal ramus is rather striking, but certainly of no specific value, for several forms possess jaws just as shallow, notably

Merycodus necatus sabulonis Matthew and Cook (1909, A.M. No. 14109), and *Cosoryx* (*Subcosoryx*) *cerroensis* Frick (F:A.M. Nos. 32938, 30982, 31996). A feature of greater significance is the length of the diastema between mandibular symphysis and $P\bar{2}$. In Frick's table VIII of "Comparative Measurements and Ratios of Merycodontini Mandibles" (Frick 1937, pp. 384–390) no form except *C.* (*Subcosoryx*) *cerroensis* shows a post-symphyseal diastema so great in comparison with the longitudinal diameter of $M\bar{3}$.

$M\bar{2}$ and $M\bar{3}$ have reached an advanced stage of hypsodonty. $M\bar{1}$ is less hypsodont, while the premolars retain rather short crowns. In general, the cheek-teeth might be said to exhibit a slightly more advanced stage of hypsodonty than that displayed in many, if not in most, of those figured by Frick. The Avawatz teeth are considerably more hypsodont than those from the Barstow, and slightly less so than those from the Ricardo as illustrated by Merriam and by Frick. The shortening of the premolar tooth-row, in comparison with the length of the molar tooth-row, is even more striking in the lower series than in the upper dentition. This shortening, which is rivaled only by the extreme case found in *C.* (*Subcosoryx*) *cerroensis* Frick (see tables of measurements, Frick 1937, pp. 384–390), may be of specific value. Lateral compression, especially in the premolars, is pronounced. Frick states that the species *C.* (*Subcosoryx*) *cerroensis* is "characterized by reduction of the premolars, particularly $P\bar{2}$ and $P\bar{3}$, and elongation and slenderness of the diastema" (Frick 1937, p. 392).

The crown-pattern of the lower dentition follows closely the merycodont-antilocaprid pattern. The molars have a strongly developed anterior parastylid which forms a very sharp ridge extending from the crown almost to the base of the tooth. The third lobe in $M\bar{3}$ is strongly developed, with a triangular to egg-shaped crown-pattern, slightly flattened on the interior side, and having the larger end posterior. The crown-pattern of the premolars is very simple, consisting of only three internal ribs separated by open valleys which do not reach down to the cingulum. On the external side of the premolars, immediately posterior to the median transverse crest, lies a broad but pronounced depression extending from cingulum to crown. The anteroexternal side of the typical premolar is rounded and convex. Since considerable variation may occur in the crown-pattern of $P\bar{4}$, that pattern may be of specific value. In all Avawatz specimens it consists of three simple transverse crests.

Several mandibles in which $M\bar{2}$ is erupting still retain the $Dm\bar{4}$. This milk tooth is short-crowned and consists of three major lobes with simple molariform crown-pattern. Of these crescentic lobes the anterior is the smallest, being about one-half the size of the posterior lobes.

The material representing the appendicular skeleton is fragmentary. Various phalangeal elements and extremities of the longer limb bones resemble closely the corresponding parts in *Antilocapra americana*. Measurements indicate that the form from the Avawatz is slightly larger than *Merycodus osborni* from Pawnee Creek, Nebraska (Matthew 1904) and *M.* near *necatus* from Ricardo, California. On the other hand, another series of specimens from the Ricardo and *M. necatus* from the Barstow formations slightly surpass the Avawatz material in size.

Discussion of nomenclature—The single antilocaprid species in the Avawatz fauna is referred to *Merycodus* cf. *cerroensis* (Frick). In a recent publication (Frick 1937) the status of the genus *Merycodus* is questioned. Frick states (p. 276): "The genotypic species, *Merycodus necatus* Leidy

(1854), was based on fragmental and indefinitely characterized teeth from the Bijou Hills and remains indeterminate." He further states, "The Merycodontini are divided between three main—*Ramoceros* n.g., *Cosoryx* Leidy, and *Meryceros*, n.g.—and several minor groups . . . it is impossible as yet to determine which of these groups is represented by the lost type of *Merycodus* Leidy." Yet in at least three citations (pp. 292, 315, and 334) Frick expresses his conviction that *Merycodus* may "prove to be synonymous with" *Cosoryx*, and on two occasions (pp. 345 and 408) he definitely refers to *Cosoryx* some material which was originally identified as belonging to the genus *Merycodus*. Not once does Frick suggest that material previously referred to *Merycodus* might actually belong to one of the major or minor groups of the Merycodontini other than *Cosoryx*.

To be sure, as Frick points out, the original type was very inadequately characterized in Leidy's description of material from Bijou Hill (Leidy 1854). A few years later, however, Leidy without the slightest hesitation refers some excellent material from the Niobrara back to his original type (Leidy 1869). This material, more complete than the original type, Leidy described and illustrated in detail. It is to this later description that subsequent authors have turned again and again for the type species of the genus. Thus, though never formally defined as such, the material referred by Leidy in 1869 to the genus *Merycodus* is essentially the hypotype [1] of the genus.

A minor argument proposed by Frick in favor of dropping the genus *Merycodus* consists in the fact that at present the type material cannot be located. Obviously, the temporary misplacement or even complete loss of a type specimen cannot render a genus invalid, though, indeed, it may make comparison with the type somewhat difficult. It must be borne in mind that "a generic category can have, in the final analysis, only a single type, which is a species, and not, as many have thought, a specimen . . ." (Schenk and McMasters 1936). It is important to recognize that the species, being intangible, is not lost, and hence the genus *Merycodus* cannot be discarded. The only loss is the type specimen for the species. To rectify this, a neotype, providing that more material can be obtained at Bijou Hill, or a neoholotype [2] from another locality should be set up. It is the contention of the present writer that the material described by Leidy in 1869 fulfills just such a category.

While the above arguments for retention of the genus *Merycodus* are academic at best, there exists one very important point of practical significance in favor of retaining that generic name, namely that of precedent and past usage. Only confusion of the literature can result from the substitution of *Cosoryx* for *Merycodus*.

Relationships—Since the presence of a long diastema and reduction of the premolars, both upper and lower, are regarded as progressive characters, the merycodont from the Avawatz must be regarded as an advanced form. Lengthening of the molar tooth crowns likewise has reached an advanced stage, being considerably greater than in specimens from the Barstow and Cuyama and slightly less than in the Ricardo types. To what extent the form and pattern of $P\bar{4}$ may be used in determining the stage of advancement remains uncertain. In the position of the frontoparietal suture, rela-

[1] Hypotype: a described or figured specimen, used in publication in extending or correcting the knowledge of a previously defined species (see Frizzell 1933).

[2] Neoholotype: a new holotype selected by a subsequent worker in the event of loss of the original type material (see Frizzell 1933).

tively close behind the horn core pedicles, the Avawatz merycodont is definitely not so advanced as either the Barstow or the Ricardo forms. Horn cores similar to the Avawatz material have been found in both Ricardo and Barstow deposits (horizons unknown).

With due consideration of these evolutionary characters, the conclusion is reached that the merycodont from the Avawatz Mountains represents a species considerably more advanced than those from the Barstow and Cuyama and slightly less advanced than that from the Ricardo. In every way the species appears to be nearly related to *Merycodus cerroensis* (Frick) from Round Mountain Quarry, New Mexico.

Measurements (in millimeters) and ratios

	No. 1997 C.I.T.	No. 1999 C.I.T.
Postsymphyseal diastema	36.0	
$P\overline{2}$–$M\overline{3}$, total length	51.4	
$M\overline{1}$–$M\overline{3}$, total length	36.0	
$P\overline{2}$–$P\overline{4}$, total length	15.4	
$\frac{M\overline{1}\text{–}M\overline{3}}{P\overline{2}\text{–}P\overline{4}}$ ratio	2.3	
$\frac{M\overline{3}\text{, anteroposterior diameter}}{\text{Postsymphyseal diastema}}$ ratio	0.48	
$P\overline{2}$, anteroposterior diameter	3.6	3.5
$P\overline{2}$, transverse diameter	1.6	1.4
$P\overline{3}$, anteroposterior diameter	5.3	
$P\overline{3}$, transverse diameter	2.4	2.0
$P\overline{4}$, anteroposterior diameter	6.4	
$P\overline{4}$, transverse diameter	3.0	
$M\overline{1}$, anteroposterior diameter	8.9	8.9
$M\overline{1}$, transverse diameter	5.3	3.9
$M\overline{2}$, anteroposterior diameter	11.4	11.5
$M\overline{2}$, transverse diameter	5.9	3*
$M\overline{3}$, anteroposterior diameter	17.3	
$M\overline{3}$, transverse diameter	4.7	
$Dm\overline{4}$, anteroposterior diameter		8.0
$Dm\overline{4}$, transverse diameter		3.9

	No. 1995 C.I.T.	No. 1996 C.I.T.
$P\underline{2}$–$M\underline{3}$, total length	42.8	
$P\underline{2}$, anteroposterior diameter	4.6	
$P\underline{2}$, transverse diameter	2.5	
$P\underline{3}$, anteroposterior diameter	5.2	
$P\underline{3}$, transverse diameter	3.0	
$P\underline{4}$, anteroposterior diameter	5.9	
$P\underline{4}$, transverse diameter	3.7	
$M\underline{1}$, anteroposterior diameter	8.2	8.7
$M\underline{1}$, transverse diameter	5.8	6.4
$M\underline{2}$, anteroposterior diameter	11.0	9.3*
$M\underline{2}$, transverse diameter	6.3	5.9
$M\underline{3}$, anteroposterior diameter	9.5	
$M\underline{3}$, transverse diameter	5.0	
$Dm\underline{4}$, anteroposterior diameter		6.5
$Dm\underline{4}$, transverse diameter		4.5

* Partially erupted.

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Aerial photograph of the southeastern flanks of the Avawatz Mountains, California. Quartzite and white marble intruded by darker igneous rocks make up the basement complex. Near the range and in the background the Tertiary sediments dip regularly off the basement complex. In the foreground and to the left the Tertiary sediments are closely folded and faulted.

Plate 2

Fig. 1—*Pseudælurus intrepidus* Leidy. No. 2309, left ramus, lateral view. ×1.

Fig. 1*a*—*Pseudælurus intrepidus* Leidy. No. 2309, left ramus, occlusal view. ×1.

Fig. 2—Canid, indet. No. 2308, right maxillary dentition, lateral view. ×1.

Fig. 2*a*—Canid, indet. No. 2308, right maxillary dentition, occlusal view. ×1.

Fig. 3—*Trilophodon* cf. *simplicidens* Osborn. No. 1984, mandible, occlusal view. ×¼.

Fig. 4—*Pliohippus ?*, sp. No. 2313, lower incisors and canines, occlusal view. ×1.

Fig. 5—*Pliohippus ?*, sp. No. 2312, $M\underline{1}$, occlusal view. ×1.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Pliocene, Avawatz Mountains, California.

2
2a
5
4
3
1a
1

Plate 3

Fig. 1—*Procamelus coartatus* Stirton. No. 1989, palate with dentition, occlusal view. ×¾.

Fig. 2—*Procamelus coartatus* Stirton. No. 2316, left ramus, P$\bar{3}$–M$\bar{2}$, lingual view. ×¾.

Fig. 3—*Procamelus coartatus* Stirton. No. 2318, right ramus, M$\bar{2}$–M$\bar{3}$, lateral view. ×¾.

Fig. 4—*Procamelus coartatus* Stirton. No. 2319, Dm$\bar{4}$, lateral view. ×¾.

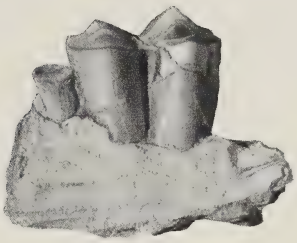
Fig. 5—*Procamelus coartatus* Stirton. No. 2317, M$\bar{2}$, lateral view. ×¾.

Fig. 6—*Merycodus* cf. *cerroensis* (Frick). No. 1995, right maxillary dentition, P$\underline{2}$–M$\underline{3}$, lateral view. ×1½.

Fig. 6*a*—*Merycodus* cf. *cerroensis* (Frick). No. 1995, right maxillary dentition, P$\underline{2}$–M$\underline{3}$, occlusal view. ×1½.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Pliocene, Avawatz Mountains, California.

6



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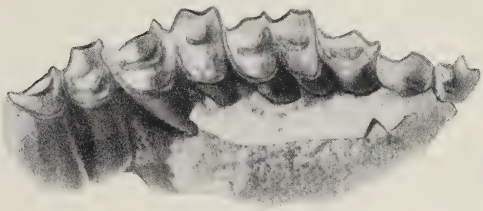

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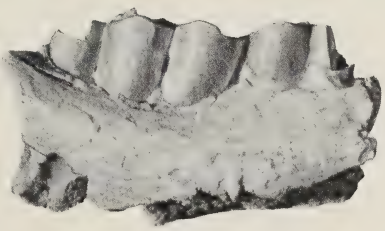

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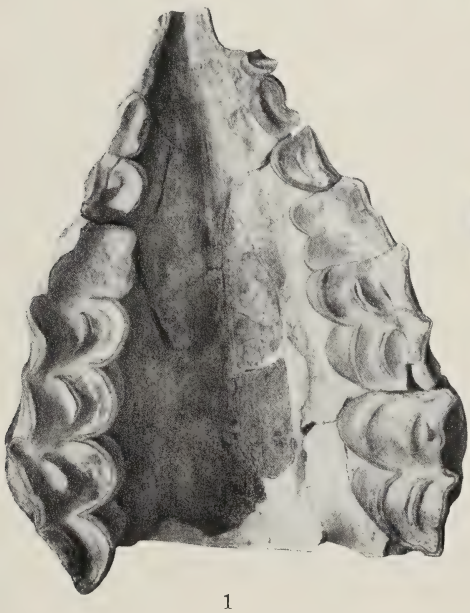

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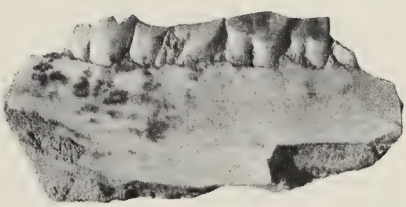

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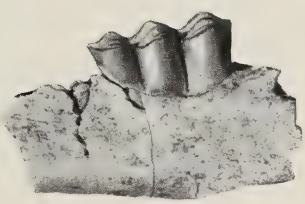

4

Plate 4

Fig. 1—*Procamelus coartatus* Stirton. No. 2324, proximal end of radius, anterior view. ×½.

Fig. 1*a*—*Procamelus coartatus* Stirton. No. 2324, proximal end of radius, superior view. ×½.

Fig. 2—*Procamelus coartatus* Stirton. No. 2334, medial phalanx, anterior view. ×½.

Fig. 3—*Procamelus coartatus* Stirton. No. 2321, mandibular symphysis, ventral view. ×½.

Fig. 4—*Procamelus coartatus* Stirton. No. 2328, distal end of tibia, posterior view. ×½.

Fig. 4*a*—*Procamelus coartatus* Stirton. No. 2328, distal end of tibia, inferior view. ×½.

Fig. 5—*Procamelus coartatus* Stirton. No. 2325, distal end of radius-ulna, anterior view. ×½.

Fig. 5*a*—*Procamelus coartatus* Stirton. No. 2325, distal end of radius-ulna, inferior view. ×½.

Fig. 6—*Procamelus coartatus* Stirton. No. 2329, cannon bone, anterior view. ×½.

Fig. 7—Camelid, sp. No. 2336, distal end of tibia, posterior view. ×½.

Fig. 8—Camelid, sp. No. 2340, proximal phalanx, anterior view. ×½.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Pliocene, Avawatz Mountains, California.

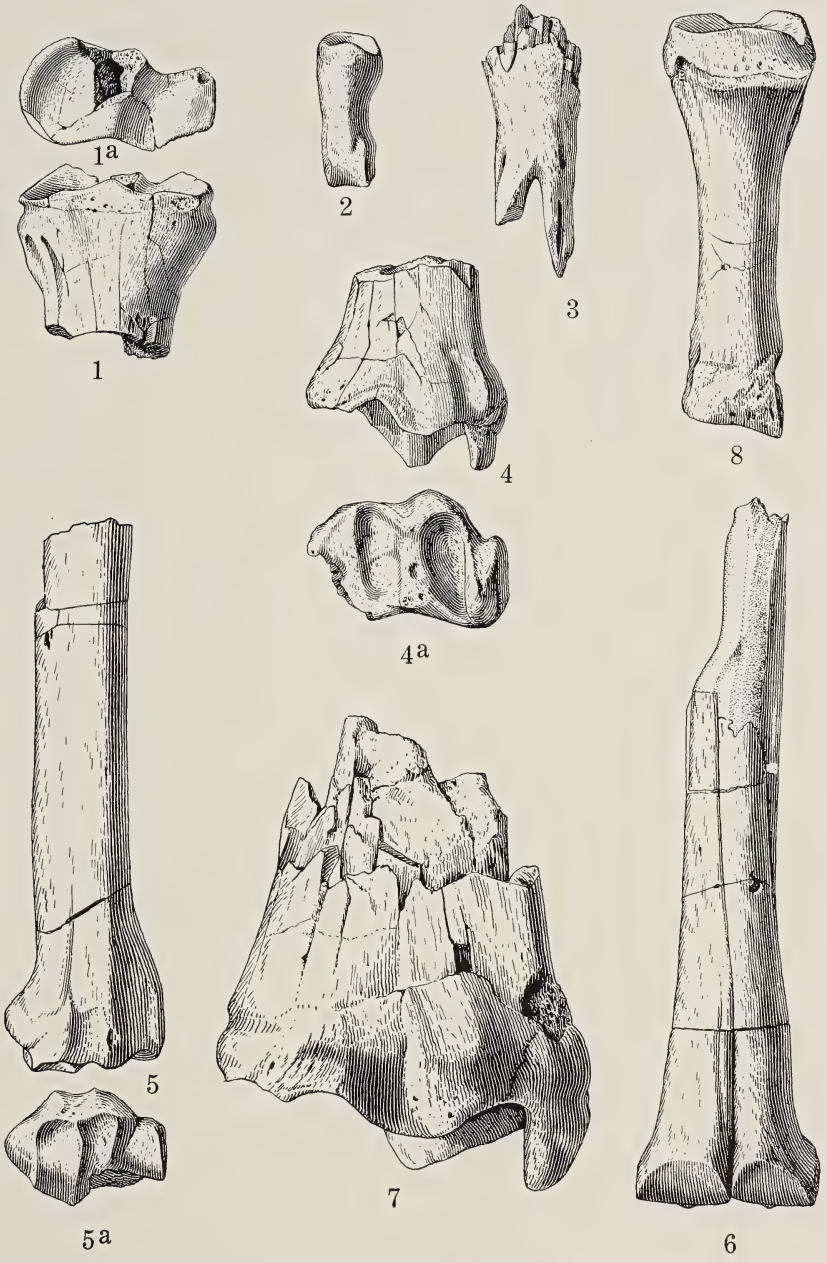
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Plate 5

Figs. *a*, *b*, *c*, *d*—*Merycodus* cf. *cerroensis* (Frick). Nos. 1992, 1994, 1993, and 1991, horn cores, oblique view. ×½.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Pliocene, Avawatz Mountains, California.

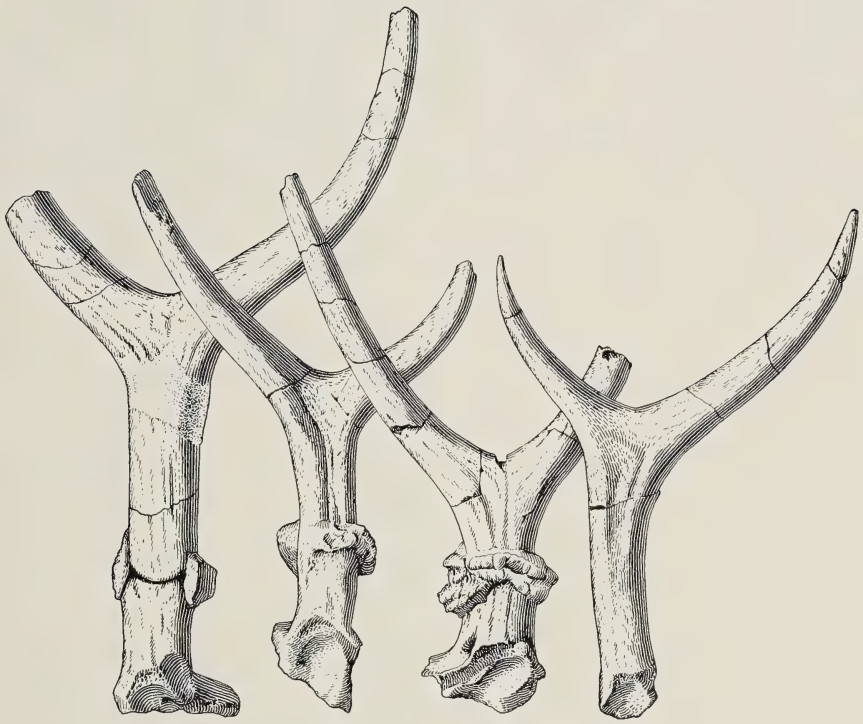
a
b
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Plate 6

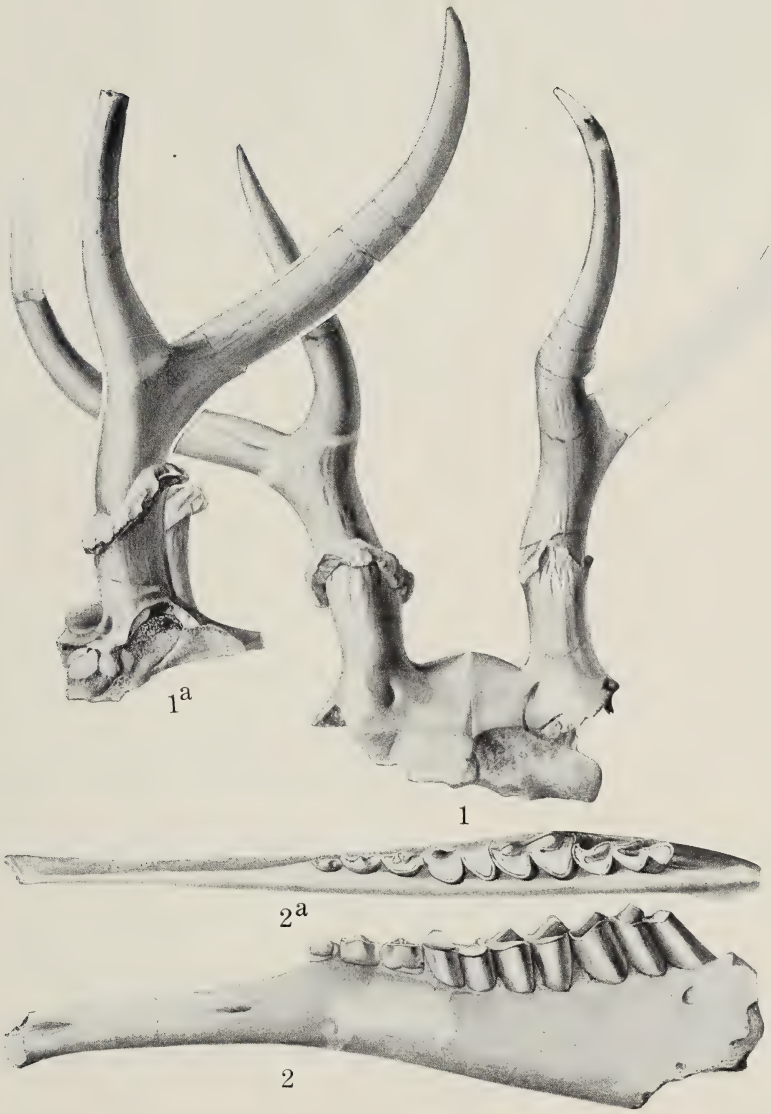
Fig. 1—*Merycodus* cf. *cerroensis* (Frick). No. 1990, frontlet with horn cores, anterior view. ×½.

Fig. 1*a*—*Merycodus* cf. *cerroensis* (Frick). No. 1990, frontlet with horn cores, lateral view. ×½.

Fig. 2—*Merycodus* cf. *cerroensis* (Frick). No. 1997, left ramus, $P\bar{2}$–$M\bar{3}$, lateral view. ×1.

Fig. 2*a*—*Merycodus* cf. *cerroensis* (Frick). No. 1997, left ramus, $P\bar{2}$–$M\bar{3}$, occlusal view. ×1.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Pliocene, Avawatz Mountains, California.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CONTRIBUTIONS TO PALEONTOLOGY

II

RODENTS AND LAGOMORPHS OF THE LATE TERTIARY AVAWATZ FAUNA, CALIFORNIA

By Robert W. Wilson

With one plate

[Issued May 18, 1939]

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RODENTS AND LAGOMORPHS OF THE LATE TERTIARY AVAWATZ FAUNA, CALIFORNIA

INTRODUCTION

A number of fragmentary rodent and lagomorph specimens are included in the fossil mammal collection from the Avawatz Mountains, California, reported on by Paul C. Henshaw.[1] The following statement has been prepared in order to complete the study of the fossil mammalian fauna from this region.

The assemblage consists chiefly of heteromyid rodents, of which three species are present. A single specimen of the cricetine *Peromyscus* and several individuals representing one, perhaps two, species of the extinct hare, *Hypolagus*, are also recorded. An upper Miocene or lowest Pliocene age for the rodent fauna is indicated, more probably the latter.

SYSTEMATIC DESCRIPTION OF SPECIMENS

ORDER RODENTIA

FAMILY HETEROMYIDÆ

Perognathoides cf. tertius (Hall)

Perognathoides is a pocket mouse belonging to the subfamily Perognathinæ. It is close to *Perognathus* but is characterized by the precocious development of crown height and the development of certain features possessed by the Dipodomyinæ and Heteromyinæ. In development of crown height without attendant lengthening of the pattern-bearing portion of the tooth, presence of a small lingual style in $P\underline{4}$, presence of an X-pattern in $P\overline{4}$, and asulcate upper incisors, the Avawatz material agrees with that of the type species and that of referred species. Teeth clearly showing the unworn pattern are available for the first time. The species represented seems to be closest to *P. tertius* [2] of the Fish Lake Valley fauna but perhaps is new. This is the first established species of the genus, but unfortunately the known specimen represents a very heavily worn dentition.

Description of material—Specimens include a fragment of maxillary with left $P\underline{4}$–$M\underline{2}$, No. 2511; another fragment of maxillary with left $M\underline{1}$–$M\underline{3}$, No. 2512; an incomplete right ramus with $P\overline{4}$–$M\overline{2}$, No. 2517; a portion of a right ramus with $P\overline{4}$–$M\overline{1}$, No. 2518; an incomplete left ramus with $P\overline{4}$, No. 2519; a right $Dp\overline{4}$, No. 2521; and various isolated cheek-teeth, fragments of jaws, and miscellany, Nos. 2513–2516, 2520–2521; Calif. Inst. Tech. Coll. Vert. Pale.

The upper incisors are asulcate. $P\underline{4}$ is the largest of the superior cheek-teeth. The posterior loph is about comparable in size to $M\underline{1}$, larger than $M\underline{2}$. $M\underline{1}$ is wider than $M\underline{2}$, and at least as long. Both teeth are oval in

[1] P. C. Henshaw, Carnegie Inst. Wash. Pub. No. 514, I, pp. 1–30, 1939.

[2] E. R. Hall, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 19, no. 12, pp. 297–298, figs. 2–4, 1930.

A. E. Wood, Ann. Carnegie Mus., vol. 24, pp. 95–96, 1935.

outline. M3 is noticeably reduced. In section it is subrounded, slightly ovate with a shallow posteroexternal inflection.

The anterior column of P4 is less than half the size of the posterior one, perhaps more than a third. Both lophs are oval in outline, uniting at the center of the tooth. The hypocone is somewhat posterior to metacone and entostyle. A small lingual cuspule is present on the protoloph.

In M1 an anterior cingulum extends across the tooth. The protocone is separated from it by a valley. This cusp projects somewhat into the central valley. Both protocone and hypocone are more cuspate than the other cusps, while paracone and metacone are produced as styles. The two lophs are first joined at the lingual border. The valley between the lophs is essentially level; hence the transition from a two-lophed stage to a simple enamel ring with shallow buccal inflection is abrupt. This buccal fold is present for some time.

Paracone and metacone of M2 are slightly less styliform than in M1. Separation of protocone from anterior loph is less pronounced. The hypocone is less cuspate. In M2 the posterior loph is narrower than the anterior one. Lingual union of the lophs is soon effected. With increased wear the next point of attachment is between paracone and metacone, but the valley between the crests is practically level. The external fold is persistent.

No unworn third upper molars are present in the collection.

The lower jaw is similar to that in *Perognathoides tertius*. The masseteric crest is more or less horizontal, rising at the anterior end. The incisors are normal.

$P\bar{4}$ is a somewhat elongated tooth, narrower than the following molar. The anterior column is slightly oblique. Cusps are strongly united in an X-pattern except at the apex of the tooth. A small buccal cuspule is commonly present in the posterior loph. Persistent and shallow external, and especially internal, folds are present even in advanced wear.

$M\bar{1}$ and $M\bar{2}$ have essentially the same occlusal pattern, but $M\bar{1}$ is larger and longer anteroposteriorly. A partial Y-pattern is developed, the cingulum generally being divided into two or three small cuspules. The hypostylid is small. Two lophs persist for a short time at least after the individual cusps are worn away. The lophs unite almost at once along the whole width of the tooth, but shallow internal folds are persistent.

$M\bar{3}$ is reduced. A tiny hypostylid is present, but no Y-pattern.

The cheek-teeth are high-crowned, a characteristic feature of the genus.

The Avawatz material includes one milk-tooth, a $Dp\bar{4}$, No. 2521. This tooth bears a single cusp anteriorly, two connected cusps medianly, and two posteriorly. A prominent cingulum extends around the external margin of the tooth, and the outer row of three cusps connects to it. The cusps tend to unite with the cingulum in transverse rows rather than anteroposteriorly. Wood considers the four posterior cusps to correspond to the four cusps of the permanent premolar, the anterior one to the anteroconid.[1] The Avawatz milk-tooth resembles more closely the milk-teeth of dipodomyines than it does the perognathines.

Comparisons—Compared with the type of *Perognathoides tertius* of the Fish Lake Valley rodent fauna, the specimens in the collection of the California Institute are slightly larger; the enamel of the cheek-teeth is thicker; M1 and M2 are somewhat broader transversely; M3 with respect to M2 is probably more reduced; $M\bar{2}$ with respect to $M\bar{1}$ is slightly more reduced; and $P\bar{4}$ is slightly more quadrate. Lower jaws appear to be comparable

[1] A. E. Wood, *op. cit.*, pp. 219–220, 1935.

so far as the evidence goes. Extreme wear in the Fish Lake Valley specimen prevents any comparison on pattern detail, but the two forms are not noticeably different.

Perognathoides quartus (Hall) [1] is the genotype species. The Avawatz form has a smaller M2/2 with respect to M1/1; M1 is broader transversely; the lingual cusp in the protoloph of P4 is perhaps slightly less developed; protoloph-metaloph union in P4 may be more nearly in the center of the tooth; and P4 is narrower transversely. Compared with the upper dentition of the type of *P. quartus*, our specimens are larger with thicker cheek-tooth enamel. However, the referred lower jaw of *P. quartus* has larger teeth, and the enamel is as thick or perhaps thicker. The latter specimen is least like the Avawatz specimens of any of the Fish Lake Valley fossils.

Perognathoides halli Wood [2] of the Barstow is a more primitive species than those from Fish Lake Valley. *P.* cf. *tertius* seems to be at least slightly larger with more reduction of the posterior two molars, and with apparently slightly thicker cheek-tooth enamel. The lower molars of the Avawatz species do not develop an H-pattern as in *P. halli* and, on the other hand, the latter has no lingual cuspule on the protoloph of P4.

The Cuyama vertebrate fauna of the Monterey (?) formation has furnished a fourth species of *Perognathoides*, *P. cuyamensis* Wood.[3] According to Wood, *P. cuyamensis* is close to the Barstow species but slightly more advanced. The Avawatz species, *P.* cf. *tertius*, is larger than the Cuyama form, and in addition the union of the cusps of P4 is more highly developed, the inflections probably less deep in a comparable stage of wear. M2 is relatively smaller. The enamel, however, seems thick in both species, and P4 is essentially the same.

Measurements (in millimeters) of Perognathoides cf. tertius (Hall)

	No. 2511 C.I.T.	No. 2512 C.I.T.
P4–M2, anteroposterior length	3.9	
M1–M3, anteroposterior length		3.1
P4, anteroposterior diameter	1.7	
P4, greatest transverse diameter	1.6	
M1, anteroposterior diameter	1.2	1.2
M1, greatest transverse diameter	1.7	1.65
M2, anteroposterior diameter	1.1+	1.1
M2, greatest transverse diameter	1.45	1.4
M3, anteroposterior diameter		0.85
M3, greatest transverse diameter		1.0

	No. 2517 C.I.T.
P4–M2, anteroposterior length	3.5
Depth of ramus beneath M1, measured on inside	3.1
P4, anteroposterior diameter	1.3
P4, greatest transverse diameter	1.25
M1, anteroposterior diameter	1.2
M1, greatest transverse diameter	1.5
M2, anteroposterior diameter	1.05
M2, greatest transverse diameter	1.4

[1] E. R. Hall, *op. cit.*, pp. 298, 300–301, figs. 5–8, 1930.
A. E. Wood, *op. cit.*, pp. 93–94, 1935.
[2] A. E. Wood, Amer. Jour. Sci., ser. 5, vol. 32, pp. 113–116, figs. 2–5, 1936.
[3] A. E. Wood, Amer. Jour. Sci., ser. 5, vol. 33, pp. 30–32, figs. 2–5, 1937.

Perognathoides (?), sp. undet.

A left lower jaw with $P\overline{4}$, $M\overline{2}$, and $M\overline{3}$, No. 2510, is smaller than those of *P.* cf. *tertius* and apparently pertains to a distinct species. Moreover, $P\overline{4}$ is relatively shorter anteroposteriorly, but any other characters which may exist cannot be recognized in the worn dentition of No. 2510. This species of heteromyid is comparable in size to *P. cuyamensis.* Although apparently a specimen of *Perognathoides*, No. 2510 might possibly be a jaw of *Perognathus* or *Cupidinimus.*

Measurements (in millimeters) of Perognathoides (?), sp. undet.

	No. 2510 C.I.T.
$P\overline{4}$–$M\overline{3}$, anteroposterior length	3.6
$P\overline{4}$–$M\overline{3}$, alveolar length	4.1
$\overline{I}$–$P\overline{4}$, length of diastema	3.3 *
Depth of ramus beneath $M\overline{1}$, measured on inside	2.5
$P\overline{4}$, anteroposterior diameter	1.05
$P\overline{4}$, greatest transverse diameter	1.15
$M\overline{2}$, anteroposterior diameter	1.0
$M\overline{2}$, greatest transverse diameter	1.3–
$M\overline{3}$, anteroposterior diameter	0.85
$M\overline{3}$, greatest transverse diameter	1.0

* Estimated.

Dipodomyine (?), n. gen. and sp.

What is evidently a new genus of kangaroo rats is represented by $P\overline{4}$ and $M\overline{1}$ in a fragment of ramus, No. 2509. A lower incisor is considered as belonging to the same individual. The cheek-teeth are very hypsodont but are apparently not persistent in growth, a character distinguishing this genus from the Recent *Dipodomys.* It does not appear possible to separate the two genera except by this one character. Wide enamel breaks are present in $M\overline{1}$ dividing the enamel into anterior and posterior bands. The enamel of $P\overline{4}$ is complete in the present stage of wear, but an examination of the tooth indicates that breaks would develop with additional attrition at the buccal and lingual margins of the metalophid, and at the buccal border of the protolophid. The incisor is of the slender heteromyid type.

Differentiation of enamel in a heteromyid species as old as lower Pliocene is rather surprising. The highly specialized *Dipodomys* is the only heteromyid genus with incomplete enamel bands, and not all Recent species of *Dipodomys* exhibit this character. The earliest known fossil form that does is upper Pleistocene in age. *Cupidinimus*, a late Miocene-Pliocene genus which A. E. Wood considers to be ancestral to *Dipodomys*,[1] not only has complete enamel bands but is distinctly shorter-crowned than the Avawatz specimen.

Hall figured and described from the Barstow a rodent molar,[2] U.C. No. 28542, as *Diprionomys ?*, which is similar to $M\overline{1}$ of C.I.T. No. 2509. On the Barstow specimen Wood comments, "The general shape of the tooth as figured strongly suggests either one of the most advanced recent species

[1] A. E. Wood, Ann. Carnegie Mus., vol. 24, pp. 118, 143–144, 152–154, 1935.

[2] E. R. Hall, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 19, no. 13, pp. 315–316, fig. 3, 1930.

of *Dipodomys* or else a Geomyid. . . . It is much more advanced than are any known contemporary heteromyids, and compares fairly well with such late Tertiary and Pleistocene geomyids as have been described. It certainly is not referable to any known heteromyid genus other than *Dipodomys*, and should probably be called a Geomyid." [1] Wood refers to the tooth as a high-crowned, rootless form. Undescribed specimens similar to those in the collections of the California Institute have also been obtained by the University of California from the Ricardo beds.

Claude W. Hibbard has described as *Dipodomys kansensis*, n. sp.,[2] a heteromyid from the middle Pliocene Edson Quarry. Hibbard states that the form "seems to be a transitional stage between *Cupidinimus* and *Dipodomys*." It is distinguished from the Avawatz form by its well-developed roots, which same character might justify its removal from the genus *Dipodomys*.

A specimen from the upper Pliocene Benson fauna of Arizona, consisting of $P\underline{4}$–$M\underline{1}$ and associated grooved upper incisors, A.M.N.H. No. 21835, has been referred to *Cupidinimus magnus* by A. E. Wood.[3] Roots are present on the cheek-teeth. Wood says, "While this species is too late in time to have given rise to *Dipodomys*, it is very suggestive of the intermediate stages that must have been represented in the ancestry of that genus, and is an interesting and probably closely related parallel to that line, especially in the additional character of having developed grooved upper incisors, if the ones with the fossil are correctly associated."

From the above it seems that a number of specimens are known from the upper Miocene and Pliocene which approach in their characters those of the ancestor of the living kangaroo rat. Of these, the Avawatz specimen is one of the earliest and also one of the closest. Indeed, it is hard to recognize such a form as *Cupidinimus nebraskensis* as directly ancestral to *Dipodomys* in view of the occurrence of the much more advanced Avawatz specimen in deposits that are at most only slightly later than those in which the former is found. The kangaroo rats were apparently much farther along in their development by lower Pliocene time than heretofore supposed.

The progressive characters seen in the Avawatz material may raise the question as to whether the form is a heteromyid at all. The dentition of the Geomyidæ is very close in characters to that of the Heteromyidæ, and species with rootless cheek-teeth and differentiated enamel are known from the upper Pliocene to Recent. A. E. Wood has postulated that at any stage of geologic time the dentition of the former family is always more advanced than that of the heteromyids.[4] The Avawatz genus is in about the right stage of evolution to be a geomyid but the material itself, aside from considerations of geologic age, is typically dipodomyine.

Measurements (in millimeters)

	No. 2509 C.I.T.
$P\underline{4}$, anteroposterior diameter	1.55
$P\underline{4}$, greatest transverse diameter	1.85
$M\underline{1}$, anteroposterior diameter	1.2
$M\underline{1}$, greatest transverse diameter	2.1

[1] A. E. Wood, *op. cit.*, p. 197, 1935.
[2] C. W. Hibbard, Amer. Midland Naturalist, vol. 18, no. 3, pp. 462–464, fig. 3, 1937.
[3] A. E. Wood, *op. cit.*, pp. 146–148, fig. 66, 1935.
[4] A. E. Wood, *op. cit.*, p. 81, 1935.

FAMILY CRICETIDÆ

Peromyscus dentalis Hall

A right ramus with $M\bar{1}$–$M\bar{2}$, No. 2508, represents a peromyscine form. It is distinctly smaller than specimens of *Peromyscus longidens* Hall [1] from the Barstow beds, being comparable in this regard to *P. dentalis* Hall [2] of the Fish Lake Valley fauna. Compared with the type specimen of *P. dentalis*, the Avawatz specimen has slightly narrower cheek-teeth relatively and actually, since the anteroposterior length of $M\bar{1}$–$M\bar{2}$ is the same and the transverse diameter in the latter is slightly less; but there is not over 0.1 mm. difference in either $M\bar{1}$ or $M\bar{2}$. The Fish Lake Valley type is more worn, which may account in part for the narrower, more oblique external valleys in $M\bar{1}$ and $M\bar{2}$ of the Avawatz specimen. A paratype specimen of *P. dentalis*, U.C. No. 29636, exhibits a tooth-row with a longer alveolar length, but root-holes indicate an $M\bar{3}$ about comparable in size to that in the Avawatz specimen. The distinctions noted between the Fish Lake Valley specimens and No. 2508 hardly seem of specific value.

Measurements (in millimeters) of Peromyscus dentalis Hall

	No. 2508 C.I.T.
$M\bar{1}$–$M\bar{3}$, alveolar length	3.8
$M\bar{1}$–$M\bar{2}$, anteroposterior length	2.9
$M\bar{1}$, anteroposterior diameter	1.5
$M\bar{1}$, greatest transverse diameter	1.1
$M\bar{2}$, anteroposterior diameter	1.45
$M\bar{2}$, greatest transverse diameter	1.1

ORDER LAGOMORPHA

FAMILY LEPORIDÆ

Hypolagus, sp.

Leporid specimens are extremely fragmentary, the material consisting mostly of isolated teeth and bits of limb bones. An isolated third lower premolar, No. 2506, records the presence of *Hypolagus*, and there is no reason for not assigning all specimens to this common and almost sole representative of the later Tertiary lagomorphs of North America. Most of the teeth indicate an animal smaller than *H. vetus* from the Thousand Creek, with perhaps simpler folding in the upper dentition. The species is apparently larger than *H.* cf. *vetus* from Fish Lake Valley as represented by U.C. No. 29630 figured by Hall.[3] One upper cheek-tooth, No. 2507, from the Avawatz locality is as large as any of those of topotype *H. vetus* specimens. Perhaps two species are present.

Measurements (in millimeters) of Hypolagus, sp.

	No. 2506 C.I.T.
$P\bar{3}$, anteroposterior diameter	2.9
$P\bar{3}$, greatest transverse diameter	2.65

[1] E. R. Hall, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 19, no. 13, p. 315, figs. 5–7, 1930.

[2] E. R. Hall, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 19, no. 12, pp. 306–307, figs. 15–17, 1930.

[3] *Ibid.*, pp. 308–311, figs. 23–24.

PLATE

Plate 1

Perognathoides cf. *tertius* (Hall)

Fig. 1—Left maxillary, $M\underline{1}$–$M\underline{3}$, No. 2512.
Fig. 2—Left maxillary, $P\underline{4}$–$M\underline{2}$, No. 2511.
Fig. 3—Right $Dp\overline{4}$, No. 2521.
Fig. 5—Composite $P\overline{4}$–$M\overline{3}$, No. 2520; $P\overline{4}$–$M\overline{2}$ from right side, $M\overline{3}$ from left.
Figs. 7, 7*a*—Right ramus, $P\overline{4}$–$M\overline{2}$, No. 2517. Fig. 7, exterolateral view; fig. 7*a*, occlusal view.
Fig. 8—Left $P\underline{4}$, No. 2513.
Fig. 9—Right $M\underline{1}$, No. 2515.
Fig. 12—Right $M\underline{2}$, No. 2516.

Perognathoides (*?*), sp. undet.

Fig. 11—Left ramus, $P\overline{4}$, $M\overline{2}$–$M\overline{3}$, No. 2510.

Dipodomyine (?), n. gen. and sp.

Figs. 10, 10*a*—Fragment of left ramus, $P\overline{4}$–$M\overline{1}$, No. 2509. Fig. 10, posterior view; fig. 10*a*, occlusal view.

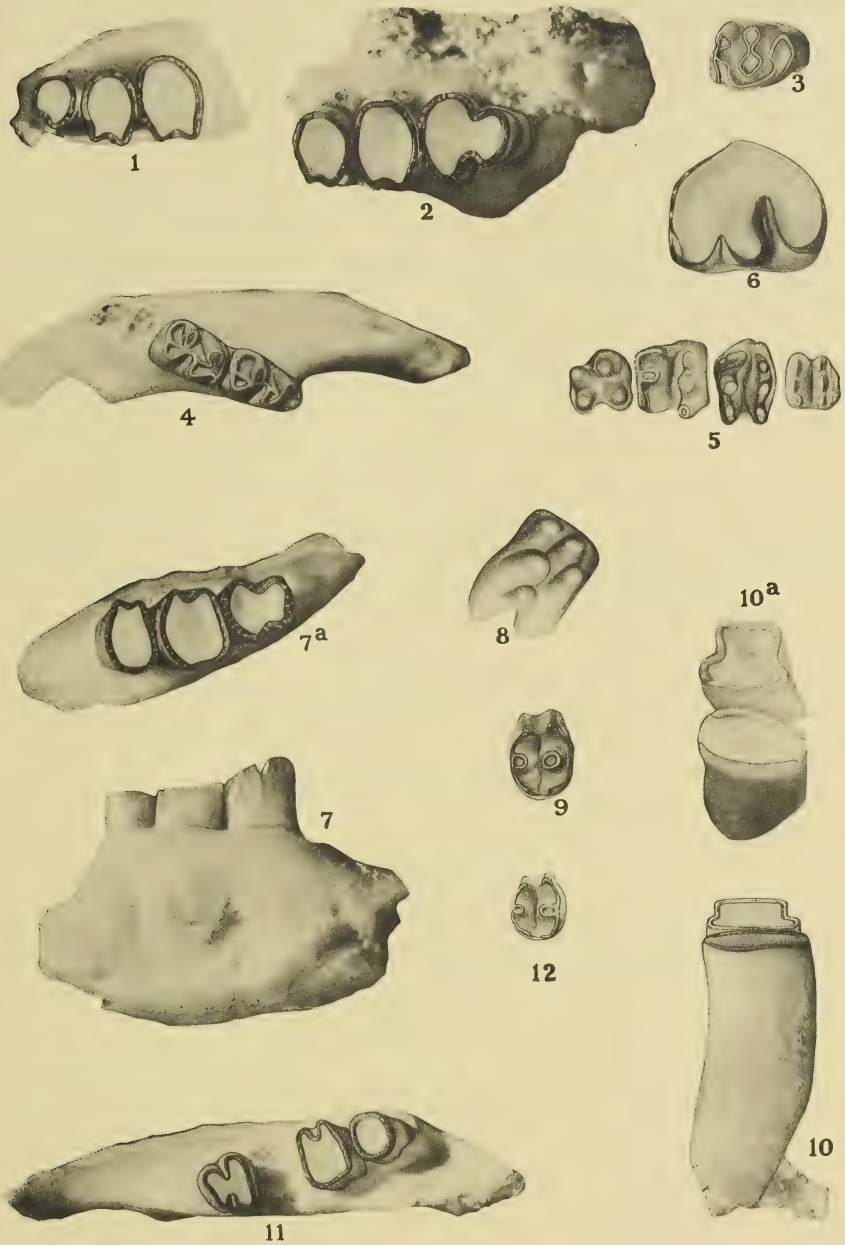
Peromyscus dentalis Hall

Fig. 4—Right ramus, $M\overline{1}$–$M\overline{2}$, No. 2508.

Hypolagus, sp.

Fig. 6—Left $P\overline{3}$, No. 2506.

Sizes of all figures approximately $\times 7\frac{1}{2}$.
Calif. Inst. Tech. Coll. Vert. Pale., Loc. 267.
Lower Pliocene, Avawatz Mountains, Kern County, California.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CONTRIBUTIONS TO PALEONTOLOGY

III

THE AVIFAUNA ASSOCIATED WITH HUMAN REMAINS AT RANCHO LA BREA, CALIFORNIA

By Hildegarde Howard and Alden H. Miller

With four text figures

[Issued May 18, 1939]

THE AVIFAUNA ASSOCIATED WITH HUMAN REMAINS AT RANCHO LA BREA, CALIFORNIA

In the course of excavating the asphalt deposits at Rancho La Brea, Los Angeles, California, in 1914, human bones were discovered in one locality, Los Angeles Museum pit number 10. In August of the same year, Dr. J. C. Merriam published a preliminary report on the discovery (*Science*, n. s., vol. 40, pp. 198–203), in which he came to the tentative conclusion that the occurrence was of considerably later age than that of the typical Pleistocene Rancho La Brea fauna. However, he stated that only after "a detailed and exhaustive study of the typical Pleistocene Rancho La Brea fauna," compared with that of pit 10, could the final conclusions as to the significance of the occurrence be determined. No further report has been published on the subject until this time.

In the light of more recent discoveries of man in association with prehistoric animals in other deposits of Quaternary age, interest in Rancho La Brea pit 10 has been revived. In the interim since 1914 considerable information regarding the fauna of the pits has been assembled, and it is now possible to make definite comparisons between pit 10 and the typical Pleistocene pits. The present paper is concerned with comparisons of the avifaunas of the two assemblages. In preparing the comparison, we have made a detailed study of the entire bird collection from pit 10, which numbers over seven thousand bones. It is probable that specimens are included additional to those originally examined by Dr. Loye Miller at the time of Merriam's report. Furthermore, as a result of intervening studies of the extinct species from the typical Pleistocene deposits, specimens which previously passed unnoticed are now recognizable, and thus the list of extinct birds represented in pit 10 is increased to nine. Miller's report (Merriam, *op. cit.*, p. 201) included four extinct species from this pit. However, three of these were thought to have been entombed at a different time from the other bones. Regarding this point, Merriam says (*loc. cit.*): "A small collection found near the upper end of the north chimney contains a number of birds which according to Dr. Miller are quite different from those certainly known from the two chimneys. The matrix in which this small collection was found is also different from that in the chimneys. It seems probable that these specimens represent an older fauna embedded in a relatively ancient deposit through or near which the north chimney passed."

In view of the possibility that the other extinct species now identified also belong to this "small collection" which was not segregated clearly as a unit from the rest of the material from pit 10, we have carefully reviewed available records concerning the 1914 excavations. The following account is based upon the field notes of L. E. Wyman, who was in charge of the Los Angeles Museum work.

The initial cut, 3½ feet in width, revealed a matrix of tar-soaked sand containing quantities of bones of birds and small mammals. Extension of this cut on its southeast side showed the deposit to be funnel-shaped. Presumably this is the deposit which Merriam refers to as the south chimney and which we shall now call funnel number 1. To the north of this funnel, and in the initial cut, a "dike or chimney of partly hardened asphaltum" was encountered "crowding in . . . from N.E." This deposit widened gradually and slanted in a southwesterly direction as it was traced downward, until at a depth of about 8½ feet it had extended fully 6 feet across the excavation to connect with a tar sump. In the "dike" and at the edge of the sump, at depths from 6 feet 6 inches to 8 feet 10 inches were found the bones of the human skeleton, presumably all of one individual. The first human bones were in the hardened asphaltum, the lower ones in a tar and sand matrix.

A second funnel was encountered to the north of the first and about 3 feet from the "dike" at its upper end, but connecting with it by a narrow pipe at a depth of 8 feet. This funnel, together with the "dike," is undoubtedly Merriam's "north chimney." The funnel evidently was considered to be the vent of the chimney, and as such must have included the questionable matrix "near the upper end of the north chimney."

Though, unfortunately, only one-tenth of the bird specimens from pit 10 are now accompanied by data as to their former location in the pit, those for which data are available include over seven hundred bones which definitely are not from funnel number 2. Seven of these (all of Recent species) bear the label "initial cut, 2′–7′," and the remainder were taken below 8 feet in the "*Homo* deposit," or in the adjacent underlying sump. In addition, there are eighty bones from funnel 2, including *Buteo regalis, Teratornis merriami, Cathartes aura, Aquila chrysaetos, Neophrontops americanus, Neogyps errans, Urubitinga fragilis, Polyborus prelutosus, Anser albifrons, Asio, Tyto alba,* and *Corvus corax.* The bones of *Teratornis* are those which Merriam records at a depth of 4 feet in postulating the possible contemporaneity of this extinct bird with man. It is evident, therefore, that the whole of funnel 2 was not under question.

In the accompanying table, the specimens from funnel 2 are omitted. The figures in the first column indicate the number of individuals represented by all other identifiable specimens which bear data. Those for which no data are at hand are listed in the second column. Among the labeled specimens there are eight extinct species represented by eleven individuals. The larger collection contains nine extinct forms with twenty-five individuals. As the labeled bird specimens give evidence of being an atypical assortment, the comparison of ratios of extinct forms in the two columns is of little value. There is, however, relatively slightly greater abundance of extinct individuals in the labeled group than in the other. In any event, there can be no doubt that extinct forms did occur elsewhere in pit 10 than in the questionable matrix "near the upper end of the north chimney."

COMPARISON OF PIT 10 BIRDS KNOWN TO HAVE COME FROM THE MAIN "*Homo* DEPOSIT" WITH THOSE FOR WHICH DATA ARE NOT AVAILABLE

Species	Individuals from known localities in pit 10, other than funnel 2	Individuals from unknown localities in pit 10
Phalacrocorax auritus	1	1
Ardea herodias		1
Botaurus lentiginosus		2
Geese (3 species)	1	3
Spatula clypeata ?	1	
Nettion carolinense		1
Cathartes aura	2	8
*Coragyps occidentalis	2*	1*
Gymnogyps californianus		1
*Teratornis merriami	1*	5*
Elanus leucurus		1
Accipiter velox		1
Accipiter cooperii		1
Circus hudsonius	6	78
Buteo borealis	6	43
Buteo swainsoni	6	32
Buteo lagopus		4
Buteo regalis	3	44
*Urubitinga fragilis	1*	1*
*Morphnus woodwardi	1*	1*
Aquila chrysaetos	10	38
*Spizaetus grinnelli		4*
Haliæetus leucocephalus		3
*Neogyps errans	1*	1*
*Neophrontops americanus	2*	2*
*Polyborus prelutosus	1*	2*
Falco mexicanus	2	8
Falco peregrinus	2	13
Falco columbarius		3
Falco sparverius	1	7
Lophortyx californica		1
*Parapavo californicus	2*	8*
Grus canadensis	1	4
Squatarola squatarola		1
Oxyechus vociferus		1
Numenius americanus	1	1
Phæopus hudsonicus	1	
Catoptrophorus semipalmatus	1	1
Larus, sp.		1
Zenaidura macroura		1
Tyto alba	8	92
Bubo virginianus	1	6
Speotyto cunicularia	6	98
Asio (2 species)	7	56
Corvus corax	7	26
Corvus caurinus		1
Corvus brachyrhynchos hesperis	2	10
Sturnella neglecta	9	67
Pica nuttallii		1
Total individuals	96	686
Total species	32	50
Individuals of extinct species	11	25
Extinct species	8	9

* Extinct species.

Referring again to Wyman's notes, it is clear that nowhere in the pit 10 excavation were the typical Pleistocene mammals encountered. Discussion with Dr. Chester Stock, who has recently been reviewing the mammal bones from this pit, corroborates this fact. It would seem that, had the matrix in question been truly Pleistocene, some evidence of the typical mammals might be expected to appear also, unless its very small extent precluded this possibility. In that event, even the number of birds included must have been too small to have affected noticeably the aspect of the entire collection from the pit. In consideration of this point, together with the already noted occurrence of extinct types at depths of 8 feet in the "*Homo* deposit," we feel that the truth regarding the bones associated with the human remains will not be greatly distorted by considering the whole pit 10 collection (except funnel 2) together. Only in this way do we have sufficient numbers of specimens for proper comparison with other, more typical Rancho La Brea pits.

Considering together all of the specimens listed in the table, and making the necessary adjustments to eliminate duplication on combining the collections, the number of individual birds for pit 10 is found to be 749. These are divided into fifty-two different species, of which nine [1] are now extinct.

Over one hundred species of birds, of which sixteen are extinct, have been recorded from the Pleistocene Rancho La Brea assemblage. In separate Pleistocene pits such as Los Angeles Museum pits 3 and 4, whose individual count approaches that of pit 10, the number of recorded species is the same as in the latter pit, with the extinct forms totaling twelve in pit 3 and fourteen in pit 4. Of greater significance than the number of extinct species, however, is the abundance of individuals representing these forms. For example, the extinct vulture, *Coragyps occidentalis*, though represented in pit 10, is reduced to but three individuals, while in pit 4 it numbered over sixty. On the other hand, the Recent *Cathartes aura*, a subordinate species in the Pleistocene, outnumbers *Coragyps* in pit 10, surpassing any single Pleistocene pit in individuals represented.

In figure 1 the totals of individuals of extinct species compared with those of Recent species are illustrated graphically for pits 3, 4, and 10. The difference between pit 10 and the two Pleistocene pits is immediately apparent. In the latter the ratio of individuals of extinct species to total number of non-passerines [2] ranges from 33 to 49 per cent, whereas in pit 10 only 5 per cent of the birds are extinct.

[1] It is a question whether or not a tenth extinct species, *Ciconia maltha*, should be included among the pit 10 birds. However, as it is represented by a single fragmentary coracoid for which no data as to location in the pit are available, we have deemed it advisable to omit the species in drawing our conclusions.

[2] In calculating these ratios, the passerines (and woodpeckers) are not included. The bones of these smaller birds were less carefully collected in some of the Pleistocene excavations than in others, with consequent variations in totals resulting. Ratios would naturally be influenced by variations of this nature.

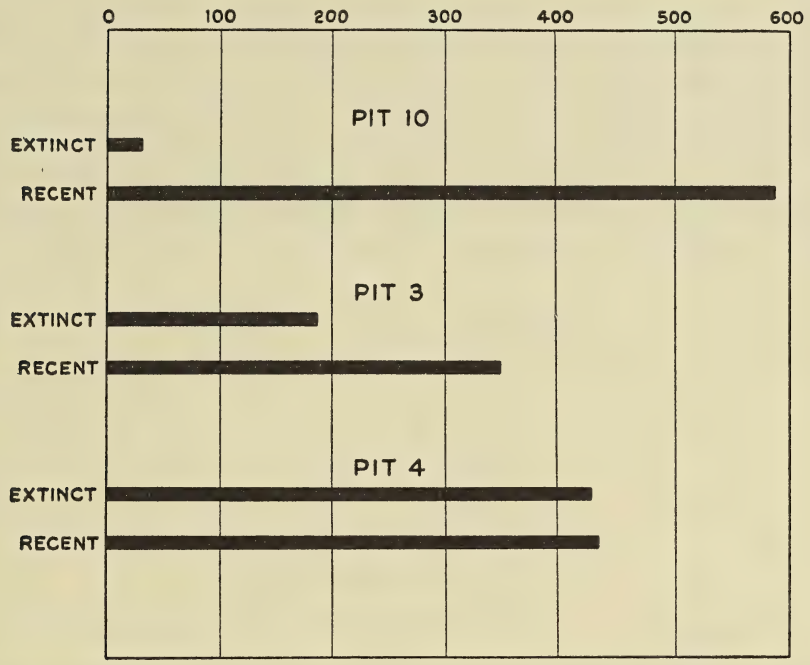

FIG. 1—Comparison of number of individuals of extinct species and Recent (existing) species as represented in pit 10 and Pleistocene pits 3 and 4.

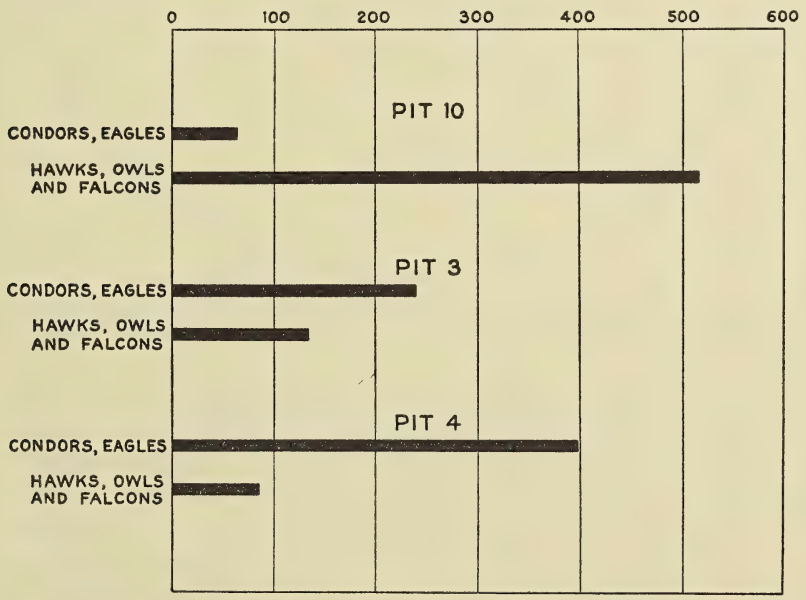

FIG. 2—Comparison of number of individuals of condors and eagles *vs.* hawks, owls, and falcons, as represented in pit 10 and Pleistocene pits 3 and 4.

Equal in significance with the reduction in extinct individuals in pit 10 are the changes within the raptorial and passerine groups.

In the raptors, the large, as well as the extinct, forms are greatly reduced in abundance, whereas individuals of the small, existing species show a marked increase. The owls, hawks, and falcons have become the dominant avian predators, although most of the larger species still have a scant representation. Figure 2 illustrates this difference between the Pleistocene pits and pit 10. The proportion of individuals of the larger birds (condors

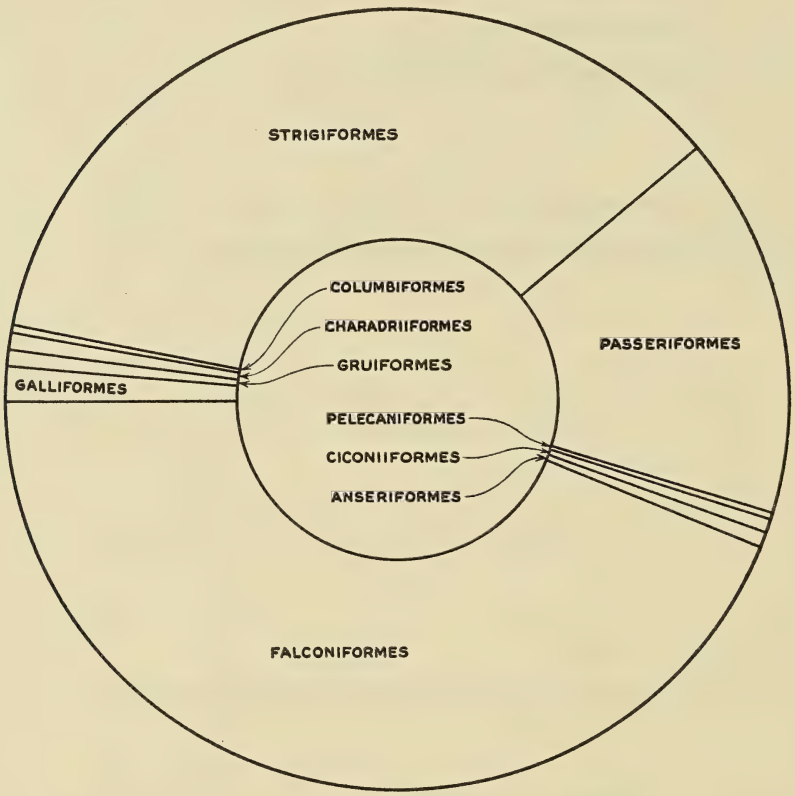

FIG. 3—Diagram showing the relative abundance of individuals in each order of birds represented in Rancho La Brea pit 10.

and eagles) relative to the total raptorial count [1] ranges from 52 to 63 per cent in the avifauna of the Pleistocene pits, but it drops to 10 per cent in pit 10. The proportion of hawks, owls, and falcons, which ranges from 13 to 29 per cent in the Pleistocene deposits, increases to 86 per cent in pit 10.

This change in the raptors is significant particularly as it reflects the general change which has taken place in the entire fauna, that is, the disappearance of the larger Pleistocene mammals, the diminishing number of

[1] Although the lesser vultures and the caracara are not represented in the chart, they are included in the raptorial totals.

large non-raptorial birds, such as the stork and turkey, and the increasing numbers of the smaller mammals and birds.

Figures 3 and 4 illustrate the differences in abundance of the various orders of birds as represented in pit 10 and in the combined Pleistocene assemblage. The outstanding difference to be noted in comparing the figures is the enlargement of the strigiform sector, with accompanying reduction of the falconiforms, in pit 10. The diminishing number of turkeys shows itself in the very small sector representing the Galliformes. The

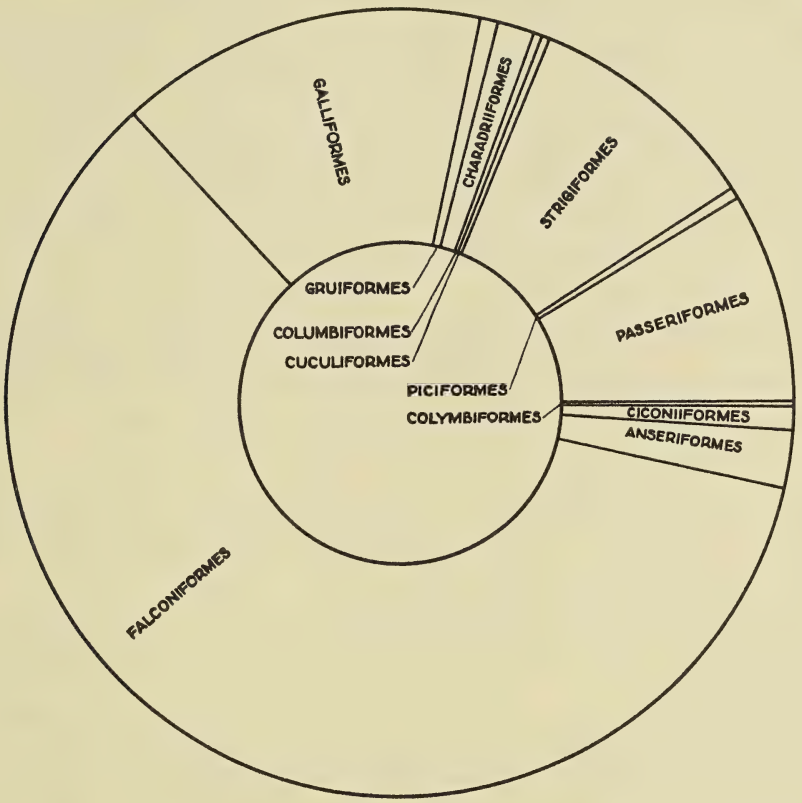

Fig. 4—Diagram showing the relative abundance of individuals in each order of birds represented in the Rancho La Brea Pleistocene. After Hildegarde Howard.

reduction of the storks is less marked, for even in the Pleistocene the storks were never represented by more than ten individuals in a single deposit and were totally lacking in three of the pits, while the turkey was one of the most characteristic birds of the area and evidently was a resident, if we may judge by the numbers of bones of very young chicks which are found in the Pleistocene asphalt.

The difference in abundance of charadriiforms is unimportant, for certain of the individual Pleistocene pits have even fewer shorebirds than are found in pit 10. The difference in the anseriforms, however, is apparent in com-

paring pit 10 with any single Pleistocene pit. Whether or not this can be taken as an indication of greater precipitation during the earlier period is problematical. In none of the pits are anserines abundant.

The passerines show a definite increase in pit 10. Lest the Pleistocene ratio be affected by those pits in which the smaller birds were overlooked, comparisons were made with the separate pits. Pit 16, from which the largest Pleistocene "micro"-fauna was recovered, shows the nearest approach to pit 10, with 157 identifiable passerines, representing 9 per cent of the total avifauna, contrasting with 16 per cent in pit 10.

More important, however, than the difference in actual numbers of passeriform individuals are the changes which may be noted within the group itself. These changes have to do with the local extinction of species which still persist in other regions. Thirty per cent of the small birds recorded from the Pleistocene pits are now locally extinct, whereas only 2 per cent of the pit 10 passerines have thus disappeared. Several of the species involved are important as indicators of biotic and climatic conditions. The changes in environment shown by the disappearance of these forms consisted of a retreat of the live-oak and brushland associations, giving way to grasslands. In pit 10 the increase in grassland types is marked. One grassland species, the meadowlark (*Sturnella neglecta*), increased, relative to total number of passerine individuals, from 12 per cent in the Pleistocene to 62 per cent in pit 10. *Pica nuttallii*, a live-oak associate, diminished from 35 per cent to 1 per cent.

Related to this diminution in live-oak associates is the absence of woodpeckers in pit 10. In most of the Pleistocene pits *Colaptes* and *Asyndesmus* are present in small numbers, and there are also records of other, more strictly forest-dwelling woodpeckers.

The environmental changes thus indicated bespeak a considerable lapse of time between the accumulation of the typical Pleistocene deposits and those of pit 10.

Looking at the avifauna of pit 10 as a whole, we find here an important link between the typical Pleistocene and the typical Recent. Nine of the sixteen extinct species associated with Pleistocene Rancho La Brea are present in pit 10, but all are so reduced in numbers as to be only one-tenth as abundant as they were in the Pleistocene. We see in this assemblage, then, an intermediate stage in the extinction of birds usually considered to be typically Pleistocene. The avifauna as a whole, however, resembles that of the Recent more closely than that of the Pleistocene. Therefore, if a line is to be drawn between these periods, pit 10, in which the *Homo* remains were found, should fall into the Recent.

CONTRIBUTIONS TO PALEONTOLOGY

IV

SKULL AND SKELETAL REMAINS OF THE CAMEL PARATYLOPUS CAMELOIDES (WORTMAN) FROM THE JOHN DAY DEPOSITS, OREGON

By Jack F. Dougherty

With one plate

[Issued June 27, 1940]

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SKULL AND SKELETAL REMAINS OF THE CAMEL PARATYLOPUS CAMELOIDES (WORTMAN) FROM THE JOHN DAY DEPOSITS, OREGON

INTRODUCTION

Before the discovery of the skull and skeletal remains of *Paratylopus cameloides* described in this paper, only scanty and fragmentary material of this form had been available to students of the Tertiary Camelidae. A fairly well-preserved skull referred to this species by Professor R. S. Lull belongs unfortunately to a juvenile individual. The present specimens furnish therefore a better basis for comparison with related species of camels leading in the direction of the later Tertiary genus *Alticamelus*.

I should like to express my indebtedness for the guidance and help given me by Dr. Chester Stock. I am also obligated to E. L. Furlong and to Dr. R. W. Wilson for suggestions and valuable assistance during the progress of the study. The wash drawings have been prepared by John L. Ridgway.

Paratylopus cameloides (Wortman)

This species of camel was described by J. L. Wortman from the John Day beds, Oregon, on the basis of the type mandibular ramus, A.M.N.H. No. 8197, and the paratypic material representing the upper dentition and fore limb elements, A.M.N.H. No. 7912. The type locality is stated to be the Cove, John Day Basin, the material coming from the upper John Day or *Promerycochoerus* beds, several hundred feet above the level of *Paratylopus sternbergi*.

The specimens here described and referred to the species *P. cameloides* represent a nearly complete skull, an incomplete mandible, and various skeletal parts, C.I.T. No. 128. This material was collected in 1927 in gray tuffaceous upper John Day beds, exposed on the west side of John Day River near the junction of the main stream and the north fork and immediately west of the Davis basalt dike (locality 22, C.I.T. Vert. Pale.).

COMPARISON OF MATERIAL

Superior dentition. The skull, C.I.T. No. 128 (plate 1), retains the complete dentition of the right side in a moderate state of wear. The incisors are slightly procumbent; they are well spaced and increase in size from first to third. $I\underline{1}$ and $I\underline{2}$ have slightly expanded and flattened crowns, very similar to those in *Oxydactylus longipes*.[1] $I\underline{3}$ is caniniform and smaller than the canine; in *O. longipes* the caniniform third incisor and canine are of equal size. The canine is sharply recurved, with an oval basal cross

[1] O. A. Peterson, Ann. Carnegie Mus., vol. 2, no. 3, pp. 434–475, 1904.

section. A long diastema separates I3 from C, this diastema being much longer than in *Paratylopus sternbergi*,[2] and nearly equal to that in *O. longipes*.

Lack of adult skull material of *P. cameloides* with complete upper and lower dentitions has resulted in some misconceptions regarding the length of the diastema between I3 and C as inferred from the length of the diastema between the comparable teeth of the lower dentition. On the basis of absence of this diastema in the type specimen of *P. cameloides*, for example, Lull concluded that no gap or at most a very short one would be found in the upper jaw.[3] Furthermore, in establishing the species *P. wortmani* from the John Day, Lull utilized the character of absence of pronounced diastema between I3 and C to distinguish this species from *P. cameloides*. No. 128 resembles closely the type *P. wortmani*. Unfortunately, it appears from Lull's illustration that the crowns of all the teeth in the type are missing, leaving only the diastemata as characters of diagnostic value.[4] The diastema between I3 and C is almost exactly equal to that in skull No. 128 of *P. cameloides*. Examination of a number of skulls of living and extinct camels emphasizes the lack of correlation between lengths of upper and lower diastemata in individuals. In *Oxydactylus brachyodontus*, for example, there is a considerable diastema between I3 and C, but none at all in the mandible. Likewise, in the juvenile skull of *P. cameloides* described by Lull there is a long diastema between I3 and C but none between the comparable teeth in the mandible. In view of this variation and in the light of the present material which has been referred to *P. cameloides*, it seems desirable to regard *P. wortmani* as a synonym of *P. cameloides*. The differences between the two forms can be attributed readily to individual variation.

In No. 128 the diastema between C and P1 is much greater than that between I3 and C. In *O. longipes* these diastemata are somewhat smaller, and in *P. sternbergi* they are considerably smaller than in No. 128. P1 is small and two-rooted, and the crown is noticeably trenchant. The length of the diastema between P1 and P2 is nearly equal to that between C and P1.

The continuous premolar-molar series is characterized by prominent external styles, particularly on the molars. The length of this series agrees closely with that in the referred specimens of *P. cameloides*. P2 is laterally compressed and consists of a primary cusp flanked by minor anterior and posterior cusps. A faint internal cingulum is present posteriorly. P3 is very similar to P2, but has a strong complete internal cingulum which approaches a crescent shape. P4 is molariform, having a well-developed crescent and internal pillar. It is subtriangular in shape with anteroexternal style very prominent. These characters are found in the type and referred specimens of *P. cameloides* and in *O. longipes*. The oblique position of P4, with reference to the alveolar border of the skull, is more pronounced in

[2] J. L. Wortman, Bull. Amer. Mus. Nat. Hist., vol. 10, art. 6, pp. 93–142, 1898.
[3] R. S. Lull, Amer. Jour. Sci., ser. 5, vol. 1, art. 26, pp. 392–404, 1921.
[4] *Ibid.*

No. 128 than in the living llama. The molars are brachydont and increase in size from M1 to M3. This contrasts with *O. longipes*, in which M2 is the widest tooth of the series, and with the llama, in which M1 is the widest. The anteroexternal style of M1 is not so well developed as that of the second and third molars. The diameters of the molars and premolars are somewhat smaller than those of the type and referred dentitions of *P. cameloides*. The differences are slight, however, and probably lie well within the limits of individual variation.

Inferior dentition. The premolar-molar series, P2–M3, is complete and continuous except for the absence of portions of P3 and M3. The incisors, canine, and P1 are missing, as well as the anterior portion of the mandible. The teeth of the cheek-tooth series increase in length, size, and width, from P2 to M3 inclusive. P2 has a high, trenchant crown, very much compressed laterally. P3 is missing, but from its alveolus one may judge that it was similar to P2 in size and shape. P4 is compressed anteriorly and expanded posteriorly. It has a strong anterointernal style and cusp. The posterior valley between the internal and external walls of the tooth is well developed, much as in *Poebrotherium labiatum*. Peterson notes the presence of this valley in P4 of *O. longipes*, but it is somewhat reduced in size in the latter. Lull remarks that the type *P. cameloides* has a small posterior cusp on the external face of P4. This probably corresponds to a projection of the external wall which with the internal wall forms the above-mentioned posterior valley. The inferior molars are long and narrow, and exhibit no noticeable differences from those in the type *P. cameloides* or in *O. longipes*.

Reference to the tables of measurements will show the extent of agreement in size of the molars and premolars between No. 128 and the type and referred specimens of *P. cameloides*. The lengths of the various diastemata in the mandible demonstrate the variability of these characters. The overall length of the inferior dentition of No. 128, determined in part by the occlusal relations of the upper and lower teeth, is seen to be extremely close to that in the type.

Skull. The skull is nearly complete, lacking only the extreme posterior portion of the supraoccipitals, the zygomatic arches, and the palatines. Lateral crushing and flattening have somewhat distorted the specimen. The basioccipital is transversely convex and has a narrow furrow along its median line, contrasting with the flattened basioccipital of *Lama huanaco*. The bullae (plate 1, fig. 1*a*) are elongate and do not crowd the basioccipital as in *Poebrotherium*. The tympano-hyal recess is well developed and divides the bulla into two nearly equal parts, whereas in *L. huanaco* these divisions of the bulla are unequal, the external one being the larger. The bullae are more robust in relation to size of skull than those of *L. huanaco*, and lack the deep posterior groove which extends from the recess to the posterior end; hence, each bulla is not completely divided posteriorly into two parts. This agrees with the condition found in *O. longipes*. The

Comparative measurements (in millimeters) of skull and upper dentition

	C.I.T. No. 128 *P. cameloides*	A.M.N.H. No. 7912 *P. cameloides*	Y.P.M. No. 10917 *P. cameloides*	Y.P.M. No. 10884 *P. wortmani*	A.M.N.H. *P. sternbergi*	C.M. No. 918 *O. longipes* ‡	*L. huanaco* ‡
Greatest length from anterior end of premaxillaries to posterior end of skull	278.0*	.....	.....	.....	212†	340	305
Greatest width across postorbital processes	120.0*	.....	.....	.....	.....	126	150
Length of sagittal crest	44.0	.....	.....	.....	37†	95	45
Length of nasals along median line	96.0	.....	.....	.....	.....	98	45
Anteroposterior diameter of orbit	42.0	.....	.....	.....	.....	45	50
Dorsoventral diameter of orbit	33.0	.....	.....	.....	.....	36	50
Length from anterior end of $I\underline{1}$ to posterior end of $M\underline{3}$	167.0	.....	.....	.....	.....	.....	.....
$I\underline{3}$, anteroposterior diameter	6.1	.....	.....	7.5	.....	.....	.....
$I\underline{3}$, transverse diameter	5.3	.....	.....	5.0	.....	.....	.....
$\underline{C}$, anteroposterior diameter	7.4	.....	.....	9.3	.....	.....	.....
$\underline{C}$, transverse diameter	7.1	.....	.....	6.8	.....	.....	.....
Length of diastema between $I\underline{3}$ and $\underline{C}$	12.5	.....	.....	12.0	3†	13	18
Length of diastema between $\underline{C}$ and $P\underline{1}$	22.0	.....	16.0	17.4	9†	14	.....
Length of diastema between $P\underline{1}$ and $P\underline{2}$	22.6	.....	20.0	22.4	13†	18	.....
Distance from $\underline{C}$ to $P\underline{2}$	49.5	.....	.....	.....	27†	40	55
Length of the $P\underline{2}$–$M\underline{3}$ series	79.0	84.5	78.5	.....	60	102	70
$P\underline{1}$, anteroposterior diameter	5.4	.....	.....	.....	.....	9	.....
$P\underline{2}$, anteroposterior diameter	9.7	11.0	.....	.....	.....	11	.....
$P\underline{2}$, transverse diameter	3.9	5.5	.....	.....	.....	6	.....
$P\underline{3}$, anteroposterior diameter	9.9	12.5	.....	.....	.....	14	.....
$P\underline{3}$, transverse diameter	5.2	7.3	.....	.....	.....	20	.....
$P\underline{4}$, anteroposterior diameter	9.7	13.0	11.0	.....	.....	14	10
$P\underline{4}$, transverse diameter	9.9	12.0	10.0	.....	.....	10	13
$M\underline{1}$, anteroposterior diameter	13.6	17.0	13.0	.....	.....	19	16
$M\underline{1}$, transverse diameter	13.8	17.5	.....	.....	.....	16	21
$M\underline{2}$, anteroposterior diameter	16.3	19.0	17.3	.....	.....	23	21
$M\underline{2}$, transverse diameter	16.3	20.0	16.5	.....	.....	20	21
$M\underline{3}$, anteroposterior diameter	18.5	18.0	20.0	.....	.....	25	26
$M\underline{3}$, transverse diameter	16.8	19.5	17.4	.....	.....	20	20

* Approximate.
† Taken from figure.
‡ Measurements after Peterson.

anteroventral lips of the occipital condyles do not extend over the basioccipital so far as in *L. huanaco*, and these two surfaces are more widely separated anteriorly and ventrally. The cranium (plate 1, fig. 1*b*) is comparatively small, elongate, and narrow. The sagittal crest is low and short but well defined above the posterior part of the parietals. The dorsoventral ridge from the inion to the superior border of the foramen magnum is broad and convex. In *L. huanaco* this crest is less rounded and is reduced in area. The frontals expand widely from the parietal suture forward and form a prominent, flat supraorbital area. The doming of the frontals and parietals behind the orbits, so pronounced in *L. huanaco*, is hence very poorly developed in No. 128. The skull slopes very gently and uniformly from the parietals to the tip of the nasals. The flaring of the supraoccipitals at the lambdoidal crest, which produces the broad shelf above the foramen magnum in *L. huanaco*, is much less developed in *P. cameloides*. The cranial region is strikingly similar to that in *P. sternbergi* and in *O. longipes* in almost every detail except size. The facial region is elongate and narrow transversely, expanding rapidly from the contact of premaxillary, maxillary, and nasal to the frontals above the orbits. The nasals are long and narrow, and are in contact with the premaxillaries for more than a third of their length. The ratio of length of nasal to length of skull demonstrates the extreme elongation of the muzzle in *P. cameloides* in comparison with other camels. The frontonasal suture outlines a narrow W with parallel lateral arms. In *L. huanaco* this suture forms a similar pattern with the lateral arms of the W more divergent. The maxillae are long and low, and taper anteriorly to meet the posterior borders of the premaxillae. The premaxillae have an elongate rhombus outline, and flatten out immediately over the incisors. They are relatively heavier than in *L. huanaco*. The anterior narial opening is long and narrow, almost oval in outline. The orbits (plate 1, fig. 1) are completely encircled by bone and their anteroposterior diameters are apparently greater than the transverse. The facial vacuity is large and extends from above the anterior end of $M\underline{2}$ to a point above the anterior border of $P\underline{2}$. The infraorbital foramen lies below the vacuity and above the anterior portion of $M\underline{1}$. Its channel extends forward to a point over the anterior border of $P\underline{4}$.

Mandible. The mandible (plate 1, fig. 1*c*) is similar in outline to that in *L. huanaco* and in *O. longipes*. It is long and slender, but robust in the region of the cheek teeth. The condyle is wide transversely as compared with that in *L. huanaco*, and the coronoid process projects slightly backward. These features appear similarly developed in *O. longipes*.

Fore limb elements. The humerus lacks the proximal end above the deltoid ridge. This element is more slender and relatively longer than that in *L. huanaco*. That of *O. longipes* is larger but has the same proportions as in No. 128. The humerus in Wortman's type, *P. cameloides*, apparently has the same characters of the trochlea as in No. 128 and approximates the latter in size and proportions. The size difference between these two

individuals approximates 10 per cent. The humerus in *P. wortmani* corresponds closely in all details to that in No. 128.

The ulna-radius is essentially complete, although somewhat fractured. Fusion of radius and ulna is complete with only a faint demarcation evident at the proximal and distal ends. The anterior upper face of the olecranon process has a groove for the extensor tendon. This feature is present in *Poebrotherium* and in *O. longipes*, but is absent in the recent camel and llama. The three articular facets of the distal end differ in size, the median facet

Comparative measurements (in millimeters) of mandible and lower dentition

	C.I.T. No. 128 *P. cameloides*	A.M.N.H. No. 8197 *P. cameloides*	Y.P.M. No. 10922 *P. cameloides*	A.M.N.H. *P. sternbergi*	C.M. No. 918 *O. longipes* ‡	*L. huanaco* ‡
Greatest height of mandible including coronoid process	131.0*	.....	.....	70†	150	158
Height of coronoid process	29.0*	.....	.....	15†	48	50
Depth of ramus at $M\overline{3}$	29.0	.....	24.5	25†	48	43
Depth of ramus at $P\overline{1}$	15.0	.....	14.4	13†	25	20
Length from anterior end of $I\overline{1}$ to posterior end of $M\overline{3}$	160.0*	165.0	.....	.....	.....	.....
Length of premolar-molar series	83.0	93.0	85.0	65	104	73
Length of diastema between $\overline{C}$ and $P\overline{1}$	.....	19.0	.....	.....	.....	.....
Length of diastema between $P\overline{1}$ and $P\overline{2}$	21.0*	21.0	12.3	11†	17	.....
$P\overline{2}$, greatest anteroposterior diameter	9.0*	10.0	9.2	.....	10	.....
$P\overline{2}$, greatest transverse diameter	3.5	.....	.....	.....	5	.....
$P\overline{3}$, greatest anteroposterior diameter	10.0	12.5	11.3	.....	12	.....
$P\overline{3}$, greatest transverse diameter	.....	4.3	.....	.....	5	.....
$P\overline{4}$, greatest anteroposterior diameter	10.9	13.0	.....	.....	12	12
$P\overline{4}$, greatest transverse diameter	5.0	5.9	.....	.....	7	8
$M\overline{1}$, greatest anteroposterior diameter	12.8	14.0	.....	.....	18	15
$M\overline{1}$, greatest transverse diameter	8.5	9.5	.....	.....	10	13
$M\overline{2}$, greatest anteroposterior diameter	15.1	17.5	15.5	.....	23	18
$M\overline{2}$, greatest transverse diameter	10.9	11.0	10.6	.....	14	15
$M\overline{3}$, greatest anteroposterior diameter	25.0	25.0	21.6	.....	31	30
$M\overline{3}$, greatest transverse diameter	12.5	12.0	10.0	.....	13	15

* Approximate.
† Taken from figure.
‡ Measurements after Peterson.

being about one-half as broad as the external and internal facets. In *O. longipes* the facets are more nearly equal. The ulna-radius resembles that in *L. huanaco*, but is smaller and the shaft is relatively longer. The ulna-radius of *P. wortmani* corresponds almost exactly in size to that in the type of *P. cameloides* and the two elements agree closely in proportions.

The scaphoid, lunar, magnum, unciform, and pisiform are preserved. These elements resemble closely those described by Peterson in *O. longipes*, but are smaller.

Hind limb elements. Only the ends of the two femora are preserved. The proximal end is somewhat smaller relatively than in *L. huanaco*, and

the head has a longer and more constricted neck. The great trochanter is situated lower on the femur than in *L. huanaco* or in *O. longipes*. The lesser trochanter is knoblike and with less sharply defined edge than in *O. longipes*. The intercondylar notch is narrow and the external condyle is larger than the internal condyle. The trochlea for the patella is much shallower than

Comparative measurements (in millimeters) of limb elements

	C.I.T. No. 128 *P. cameloides*	A.M.N.H. No. 7912 *P. cameloides*	Y.P.M. No. 10884 *P. wortmani*	C.M. No. 918 *O. longipes* ‡	*L. huanaco* ‡
Humerus:					
Length	205.0*	192†	215.0	315.0	275.0
Transverse diameter at midshaft	19.4	.....	17.0	.....	25.7
Transverse diameter of distal end	38.0	34†	38.0	.....	52.0
Ulna-radius:					
Length	300.0*	285†	305.0	440.0	360.0
Greatest width of proximal end	33.5	.....	34.0	47.0	49.3
Width at midshaft	24.8	.....	23.0	35.0	35.0
Greatest width of distal end	33.8	.....	35.5	.....	49.8
Metacarpals:					
Length		228	220.0	345.0	243.0
Width at proximal end		29†	29.5	46.2†	41.0
Combined width at midshaft		21†	21.0	33.0†	20.8
Width at distal end of III		17†	15.2	23.0	24.0
Width at distal end of IV		16†	15.7	23.0	23.8
Femur:					
Transverse diameter of proximal end	55.0	.....	.....	79.0	76.0
Diameter at midshaft	22.4	.....	22.0	30.0	31.6
Transverse diameter of distal end	48.0	.....	44.6	67.0	65.0
Tibia:					
Anteroposterior diameter of proximal end	59.0	.....	61.0	84.0	69.0
Transverse diameter of proximal end	46.3	.....	48.3	70.0	73.5
Transverse diameter of distal end	36.4	.....	.....	51.0	48.8
Metatarsals:					
Length	218.0	.....	.....	.....	240.0
Width at proximal end	26.0	.....	.....	.....	38.2
Combined width at midshaft	19.4	.....	.....	.....	19.1
Width at distal end of III	14.0	.....	.....	.....	23.0
Width at distal end of IV	14.8	.....	.....	.....	21.0

* Approximate.
† Taken from figure.
‡ Measurements after Peterson.

in *L. huanaco*. The femur is smaller and less elongate than in *O. longipes*. The femur in *P. wortmani* is evidently comparable in size to that in No. 128.

Proximal and distal portions of the tibiae are preserved. The size of these portions agrees closely with that in *P. wortmani* and is smaller than that in *O. longipes*. The cnemial crest is relatively longer than in *L. huanaco* and resembles that in *O. longipes*. The tibia of *P. wortmani* is similar in size to that of No. 128.

The tarsals that are preserved include the astragalus and navicular. The astragalus is comparatively narrower and higher than in *O. longipes* and in *L. huanaco.*

The metatarsus includes the complete metatarsals III and IV. These elements are not united but are closely applied to each other, particularly at the plantar processes. In *O. longipes* metatarsals III and IV are fused at the base of the plantar processes. In No. 128 metatarsals III and IV are of nearly equal size, IV being a trifle longer. The metatarsals flatten transversely toward midshaft and then become somewhat rounded where they diverge slightly at their distal ends. On the lower portion of the plantar process of IV is a small rugosity, faintly knoblike, which may correspond to a vestigial metatarsal V in *O. longipes,* described by Peterson.[5] On its internal side metatarsal III has a concave depression and facet with which metatarsal II may articulate. The proximal end of these elements is too poorly preserved to establish these characters definitely. In comparison with *L. huanaco,* the metatarsals in No. 128 clearly belong to a distinctly more slender, long-limbed camel.

CONCLUSIONS

On the basis of additional material of the camel *Paratylopus cameloides* now available from the upper John Day deposits of Oregon, the following characters are considered to be of generic and specific importance:

Generic characters. Dentition $I\frac{3}{3}$, $C\frac{1}{1}$, $P\frac{4}{4}$, $M\frac{3}{3}$. Skull with orbit closed posteriorly. Limbs very elongate and slender. Metatarsals closely appressed but not co-ossified. Size intermediate between *Poebrotherium* and *Oxydactylus.*

Specific characters. Skull with very elongate muzzle; deep malar fossae. I3 caniniform and smaller than C. Long diastema between I3 and C and between C and P1. Size intermediate between *Paratylopus sternbergi* and *Oxydactylus longipes.*

Lull's species *Paratylopus wortmani* is regarded as synonymous with *P. cameloides.*

[5] O. A. Peterson, *op. cit.,* p. 466, 1904.

Paratylopus cameloides (Wortman)

Skull and mandible, No. 128. Fig. 1, lateral view; fig. 1*a*, ventral view; fig. 1*b*, dorsal view; fig. 1*c*, mandible, lateral view. × ½.

Upper John Day Beds, Oregon.

Calif. Inst. Tech. Coll. Vert. Pale.

CONTRIBUTIONS TO PALEONTOLOGY

V

CALIFORNIAN PARAMYID RODENTS

By Robert W. Wilson

With two plates

[Issued June 27, 1940]

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CALIFORNIAN PARAMYID RODENTS

INTRODUCTION

Paramyid rodents are common and typical members of the Eocene rodent fauna of North America. In California, the Eocene part of the Sespe formation and the Eocene Poway conglomerate have yielded in places rather considerable collections of rodents, and paramyids are ubiquitous members of the assemblage if not always the most common type of rodent present.

Rodent collections of Eocene age have been made by the California Institute of Technology at four localities or quarries in the Sespe formation as exposed north of Simi Valley, Ventura County, and one quarry in the Poway conglomerate near the Mission San Diego, San Diego County. The Sespe quarries are situated on the north flank of the Simi anticline between Alamos Canyon on the west and Tapo Canyon on the east. Three of them, quarries 207, 202, and 150, are in the section between Alamos and Brea Canyons; the fourth, quarry 180, three miles to the east, is somewhat west of Tapo Canyon. The San Diegan occurrence, locality 249, is located in the west bank of the San Diego River approximately one-quarter mile northeast of the Mission San Diego.

About 7500 feet of Sespe is present in the Alamos-Brea Canyons section, grading upward without break into the lower Miocene Vaqueros formation, but separated at its base by an erosional interval from the marine middle Eocene Llajas formation. The zone of upper Eocene vertebrates occupies a position about 1600 feet above the contact with the Llajas, and more than 4000 feet below the Vaqueros. The stratigraphically highest rodent collection comes from quarry 150. A second quarry, locality 202, 600 feet below 150, has yielded rodent remains of older age. A third rodent faunule was obtained from locality 207, 75 feet below 202. Lastly, quarry 180 in the Tapo Canyon section furnishes a fourth rodent collection which is apparently nearly equivalent in stratigraphic position and age to those in 207 and 202. Hence, 180, 202, and 207 may be grouped together as a fauna older than that at 150. Chester Stock [1] has applied the term Tapo Ranch fauna to the former group, and Pearson Ranch fauna to the latter.

The Poway conglomerate, over 800 feet in thickness, covers a considerable part of the La Jolla quadrangle. Rodents from the Poway were obtained at quarry 249 probably not far above the contact with the underlying marine Rose Canyon shale member of the middle Eocene La Jolla formation. Marine invertebrates from the Poway conglomerate have been correlated with those of the upper Eocene Tejon. The upper part of the Rose Canyon shale is reported to occupy a position transitional between typical Domengine (marine middle Eocene) and typical Tejon. The Pliocene San Diego formation overlies the Poway conglomerate. The Poway

[1] C. Stock, paper in press.

rodent fauna is older apparently than any of the Sespe faunas, but probably post-Bridger. The Sespe Eocene faunas are definitely post-Bridger, but none is later than Duchesne River.[2] Judging from the rodent fauna as a whole, a more important faunal break is present between Poway and Tapo Ranch Sespe than between the latter and the Pearson Ranch fauna. The three faunal units recognized suggest tentative correlation with the early Uinta B or lower Wagonhound, Uinta C or Myton, and early Duchesne River respectively of the Rocky Mountain section. However, the evidence at present is insufficient, and it is quite possible that the Californian faunas as here recognized have no exact equivalents in the standard section.

Acknowledgments. I should like to express my appreciation for the splendid facilities offered me in the conduct of the researches on fossil rodents by the Division of the Geological Sciences and by Dr. Chester Stock of the California Institute of Technology. It is a pleasure also to acknowledge my indebtedness to Mr. Childs Frick for continued interest and support in the progress of these investigations. The illustrations which accompany this and the following papers are the result of a very painstaking and faithful retouching of photographs by the artist, David P. Willoughby.

FAMILY PARAMYIDAE MILLER AND GIDLEY: INTRODUCTORY STATEMENT

A satisfactory treatment of the paramyids of the Sespe and Poway is hardly possible until a comprehensive restudy of the known genera and species of the Paramyidae is made. However, since there is no immediate prospect of any such work, the present Californian species are described as best they can be in order to present a complete list of Eocene rodents from the West Coast region. It is hoped that in so doing, difficulties for a future reviser will not be increased unduly.

Paramys Leidy[3] was the first North American paramyid genus to be proposed, and most of the species described by early workers were referred to it or its assumed synonym *Plesiarctomys*. The genus *Pseudotomus*[4] was established a year after *Paramys*, but Cope soon abandoned the view that it was distinct. However, in 1910 Matthew restored it to subgeneric rank. Unfortunately, the cheek teeth of the type species, *P. hians*, are still unknown. *Paramys robustus* Marsh was referred by Matthew to *Pseudotomus*,[5] but Gidley[6] suggested that this species was a representative of *Ischyrotomus*, a subgenus proposed by Matthew (1910), and subsequently accorded generic rank.[7] Also in 1910, *Leptotomus* Matthew was established

[2] It should be recalled that elsewhere than in the section north of the Simi Valley the Sespe has yielded faunas of upper Oligocene as well as lower Miocene age.

[3] J. Leidy, Proc. Acad. Nat. Sci., Phila., p. 231, 1871.

[4] E. D. Cope, Proc. Amer. Philos. Soc., vol. 12, p. 467, 1872.

[5] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 28, art. 6, pp. 45–59, 1910.

[6] Note to O. A. Peterson, Ann. Carnegie Mus., vol. 12, nos. 2–4, pp. 60–65, 1919.

[7] O. P. Hay, Carnegie Inst. Wash. Pub. No. 390, vol. 2, p. 903, 1930.

as a subgenus, and it too has since been raised to generic status.[8] Matthew (1920) [9] made *Paramys delicatissimus* the type species of a fifth genus, *Reithroparamys*.

Since 1871 more than twenty species of "*Paramys*" have been erected and allocated to the divers genera. One new genus and six new species are proposed in the present paper. That some of the species of "*Paramys*" are synonyms of others is probable. That the number of known genera is insufficient to accommodate the described species is also probable. However, any revision of species or genera should be based on a thorough study of the large number of Bridger specimens at present referred to *Paramys delicatus* and *P. delicatior* in order to determine, if possible, the limits of individual variation and the validity of generic characters that have been used heretofore. Casual inspection of the specimens suggests that either several undescribed types are present in the *Paramys* collections or else the individual variation exceeds that usually recognized. The large number of forms may seem excessive, but the group ranges from the uppermost Paleocene to the base of the Oligocene, a considerable portion of Tertiary time. Moreover, the species may have been rather localized in space if not also in time. However, these considerations unfortunately do not lessen the difficulty of characterization of what are after all remarkably stable types from the beginning to the end of the Eocene.

Paramys is the only genus reported from the lower Eocene. It is doubtful if the genus (*s. s.*) actually occurs in rocks of this age. The type species of *Paramys*, *Reithroparamys*, and *Pseudotomus* are from the Bridger formation. *Reithroparamys* is known only from the middle Eocene, and generic characters are based chiefly on features of the skull. Matthew has stated that no clearly generic differences in the dentition separate *Reithroparamys* from *Paramys*. Since most of the upper Eocene species are known only by jaws, *Reithroparamys* can hardly be considered in connection with them.[10] *Pseudotomus* is not certainly known by any material outside of the type species, *P. hians*.

The type species of *Ischyrotomus* and *Leptotomus* are from beds of upper Eocene age. Matthew [11] has derived the former from the Bridger *Pseudotomus hians* group, the latter from the *Paramys delicatus* group (*Paramys s. s.*). In addition, *Paramys* and *Prosciurus* (?) have also been reported from strata of this stage. *Paramys* (*s. s.*) may, but probably does not, extend into the upper Eocene. *Prosciurus* (?) *robustus* Peterson [12] of the Uinta (Myton) does not seem referable to *Prosciurus* and, as suggested by Gidley, may belong to *Leptotomus*. On present evidence the former genus may be con-

[8] J. J. Burke, Ann. Carnegie Mus., vol. 23, p. 391, 1934.

[9] W. D. Matthew, Jour. Mammal., vol. 1, pp. 168–169, 1920.

[10] *Paramys sciuroides*, known by an imperfect skull, has points of resemblance to *Reithroparamys*. Whether or not a relation exists can be determined only after actual comparisons.

[11] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 28, art. 6, p. 51, 1910.

[12] O. A. Peterson, *op. cit.*, p. 65, 1919.

sidered as restricted to the Oligocene. Hence, only the genera *Ischyrotomus*, *Leptotomus*, and *Paramys* (*s. l.*) are regarded as available to the Sespe species. To these should be added a new genus from locality 207 which is discussed in the present paper.

Characters of the dentition which are of most importance for distinguishing paramyid genera are: (1) shape of incisors; (2) relative size of $P\bar{4}$; (3) breadth of molars, particularly of $M\bar{1}$ and $M\bar{2}$; (4) kind of enamel—whether wrinkled or smooth; (5) relation of posterolophid to entoconid; and (6) character of the ectolophid. Probably some individual variation exists in all these characters, and especially in (1), (2), and (6). Wrinkling of enamel must be observed in little-worn or unworn specimens, to be of much value.[13]

Ischyrotomus Matthew: Skull long, muzzle angular. Anteroinferior margin of ramus produced into a distinct flange. Incisors relatively wide, anterior face of lower incisor typically flat. Cheek teeth broad, $P\bar{4}$ typically reduced, triangular in outline. Cusps massive, basins shallow, internal exits narrowed (?). No prominent mesoconid or ectolophid. Entoconids marginal (?), not especially prominent. Typical species large. According to Matthew, skeleton small in proportion to size of skull; unguals long, not compressed, little curved.

Typical species: *I. petersoni* (type species, Wagonhound); *I. eugenei* (Myton).

Less typical: *I. californicus*, n. sp. (Poway); possibly *Paramys robustus* (Bridger).

Referred by Peterson and Hay: *I. gidleyi* (base of Myton); *Paramys compressidens* (Myton); *P. robustus* (Bridger).

Tentative: *I.* (?) *tapensis*, n. sp. (Sespe, loc. 180).

Leptotomus Matthew: Ramus without symphyseal flange. Incisors typically narrow to medium in width, convex anteriorly. Cheek teeth of moderate breadth, cusps relatively high, less massive than in *Ischyrotomus*, less basined than in *Paramys*. $P\bar{4}$ relatively less reduced and more lobate than in *Ischyrotomus*. Enamel generally coarsely wrinkled, not finely rugose as in *Paramys*, perhaps sometimes smooth (as in type species ?). Mesoconid-ectolophid well developed, entoconid relatively prominent. According to Matthew, hind limbs relatively large; unguals high, compressed.

Species: *L. grangeri* (type of genus, Uinta; upper Washakie); *L. leptodus* (upper Washakie); *L. burkei*, n. sp. (Sespe, loc. 202 and ?207); *L. kayi* (Duchesne River).

[13] Degree of wrinkling of the enamel of the cheek teeth apparently is an important character in distinguishing certain paramyids from others, but care must be exercised to make use of unworn teeth. In *Paramys* (*s. s.*), the enamel is heavily and finely wrinkled in the fresh state. With moderate wear the wrinkles are reduced to fewer but relatively coarse folds. In more advanced wear, the enamel becomes rather smooth. In such upper Eocene species as *Leptotomus burkei*, n. sp., the unworn enamel is heavily wrinkled but is not of the fine type seen in unworn *Paramys delicatus*. Such wrinkles may be heavier than in the latter species. Still other upper Eocene species are known in which the enamel is smooth in unworn teeth, as for example in *L.* (?) *caryophilus*, n. sp.

Tentative: *L.* (?) *robustus* (Peterson) (Myton); *L.* (?) *caryophilus*, n. sp. (Poway).

Paramys (*sensu lato*): Species: *Paramys sciuroides* (Myton); *P. medius* (Myton); *P. uintensis* (Wagonhound); and *P. tricus*, n. sp. (Sespe, loc. 150).

The relation of upper Eocene genera to types of the Bridger is probably essentially as postulated by Matthew (1910). However, several of the upper Eocene species are of uncertain affinities, and may represent distinct genera not heretofore recognized.

Description and comparison of the Californian paramyid species proposed in this paper are rather full in view of uncertainty in regard to relationships of middle and upper Eocene species. Comparisons of the Poway species with known Rocky Mountain types are probably less reliable than in the case of the Sespe species, since more reliance had to be placed on published descriptions and figures which are often none too complete.

In general, the Californian paramyid specimens are comparable with those from the Rocky Mountain region in degree of completeness of preservation. However, a general absence of incisors in direct association with jaws is to be noted. This fact is unfortunate in view of the weight placed on features of the incisors in generic differentiation by Matthew.

Each of the Californian quarries is usually characterized by a distinct kind or kinds of paramyid. This fact suggests a limited range geographically and ecologically, or stratigraphically, or perhaps both. However, except for locality 180, specimens are not abundant, a factor which may be important in apparently limited species range. If more than a single species is present, the species are generally quite distinct and suggest the possible presence of as many genera. Species limits are most difficult of recognition at quarry 180. Here, there appear to be not only several not too well-defined species, but also isolated specimens which resemble those from other localities. However, in only one or two instances are specimens close enough to individuals of other species to raise the question of specific identity.[14] The relative abundance of paramyids at locality 180 naturally suggests a similar difficulty of specific recognition at other quarries with an increase in material. Locality 180 specimens are very fragmentary, however, usually consisting of isolated teeth; and perhaps uncertainty as to the position of these teeth in the cheek-tooth series is as important a factor in the problem of species limits as is the increase in number of specimens. Since locality 180 material is so fragmentary, it may be that a more extensive area of drainage and deposition is represented at this quarry, but the individual teeth do not exhibit much evidence of wear by transportation, although the principal species usually differs in preservation from the others. Normally, one would not expect to find more than a single species of any genus at any one quarry. The recognition of several species at locality 180

[14] These statements are not meant to include *Paramys* cf. *minutus*, which is obviously so distinct from other species from locality 180.

would not suggest necessarily that this quarry is exceptional. The divers species, if they are to be recorded, may belong to distinct genera which cannot be recognized readily with existing material.

Sespe paramyids are on the whole of post-Bridger type. Poway species may exhibit a closer resemblance to Bridger forms, but the evidence is at present equivocal.

The order of presentation of the following species is by localities rather than by genera. This procedure has been followed because: (1) at best none of the quarry collections is exactly contemporaneous with any other, and each should be treated at present as a unit; and (2) generic assignments are frequently in doubt.

SYSTEMATIC DESCRIPTION

Locality 150: Uppermost Eocene

Paramys tricus, n. sp.

(Plate 1, figures 1, 1*a*, 2)

Type specimen. C.I.T. No. 1122, a right ramus with $\bar{I}$ and $P\bar{4}$–$M\bar{3}$.

Referred specimen. C.I.T. No. 2150, a right maxillary with $P\underline{4}$–$M\underline{2}$.

Geologic age and locality. Uppermost Eocene; Sespe beds north of the Simi Valley, Ventura County, California. C.I.T. Vert. Pale. Loc. 150.

Specific characters. Size very small but larger than in *Paramys minutus;* comparable in this character to *Prosciurus vetustus.* Metastylid ridge absent.

Description

The zygomasseteric structure is typically primitive, so far as this can be determined. $P\underline{4}$ is the smallest cheek tooth preserved. $M\underline{2}$ is slightly larger than $M\underline{1}$. In general, the teeth are broad transversely. The first molar is somewhat more quadrate in outline than the other cheek teeth. In No. 2150 the cheek teeth are rather worn but the lophs appear to be relatively low with individual tubercles indistinct. Rather well-developed hypocones are present in $M\underline{1}$ and $M\underline{2}$. $P\underline{4}$ has a very weak posterointernal cusp. Mesostyles are present in $P\underline{4}$–$M\underline{2}$. The anterior cingula are only moderately developed, apparently no more so than the posterior ones. The anterior cingulum in $P\underline{4}$ is no more prominent than in the molars.

The masseteric fossa of the ramus terminates beneath the anterior part of $M\bar{2}$. Anteriorly, the jaw is of paramyid type, with relatively short diastema and superior border which is not depressed as in modernized rodents. The exposed portion of the incisor is short. This tooth is moderate in width, and the anterior face is slightly convex.

The lower cheek teeth increase regularly in size from $P\bar{4}$ to $M\bar{2}$. $M\bar{2}$ and $M\bar{3}$ are of comparable size but the latter is somewhat longer and narrower. Wear of the dentition makes characters in the individual teeth uncertain, but the trigonids are apparently low, and the basins become shallow and broad with moderate attrition. The anterior cingula are long and not especially elevated. Externally, they are rather distinct from the protoconids. No metastylids or metastylid ridges are present; thus the teeth differ from those of *Paramys minutus.*[15] Slight spurs run inward from the protoco-

[15] R. W. Wilson, Amer. Jour. Sci., vol. 34, no. 12, pp. 453–455, 1937.

nids and outward from the entoconids. The latter cusps appear to be slightly crested and somewhat separated from the low posterolophids, but wear of the teeth makes these characters uncertain. Mesoconids are present between the outer cusps. The entoconid of $M\bar{3}$ is relatively anterior in position.

Comparisons and Relationships

Paramys tricus more closely resembles *P. minutus* (Bridger) and *P.* cf. *minutus* (Sespe, loc. 180) than it does any other early Tertiary type. The following points of difference are noted in a comparison of *P. tricus* with *P. minutus:* Sespe species is larger; $P\underline{4}$ relatively narrower anteroposteriorly; metastylid ridge absent; Sespe species much younger geologically. In addition, the hypocone in the upper molars may be better developed, and the metaconid in the lower molars may be lower and not so marginal in *P. tricus,* but wear of the cusps makes these characters doubtful. A basal stylid (at base of protoconid) present in $M\bar{1}$ of *P. minutus* is absent in $M\bar{1}$ of *P. tricus.* So far as the known material permits comparison, *P.* cf. *minutus* from locality 180 is distinguished also by the above characters.

Other upper Eocene species of "*Paramys*" are clearly distinguishable specifically from *P. tricus.* The Uinta *P. sciuroides* [16] is much larger, the upper molars are more triangular and without the hypocone, and $P\underline{4}$ is relatively larger in respect to the molars.

Paramys tricus appears to be related to *P. minutus* of the Bridger and to *P.* cf. *minutus* of the Sespe. So far as is known, there is little to prevent consideration of *P. tricus* as a relative, or perhaps even a descendant, of the earlier Sespe species. The application of the generic name *Paramys* to the present species is of course open to serious question. As has been mentioned in a previous paper,[17] *P. minutus* and *P. tricus* apparently represent a genus of paramyid new to the Eocene, and the present use of the name *Paramys* is in the loose sense employed by earlier authors. Some of the characters employed in establishing a new genus might be as follows: (1) hypocone distinct, cross-lophs of upper molars low with tubercles indistinct; (2) trigonids low, hence basins shallow and wide, anterior cingula long and distinct for much of their length; and (3) known species small. However, pending a general revision of the Eocene paramyids, or at least until more complete specimens are available, the present assignment may be permissible.

Prosciurus vetustus [18] Matthew from the Pipestone Springs lower Oligocene of Montana is comparable to *Paramys tricus* in size and apparently also in zygomasseteric relations. Since the time interval between the Sespe beds at quarry 150 and those of Pipestone Springs is probably not very great, the relationship between *P. tricus* and the genus *Prosciurus* should be considered. No. 2150 differs principally from the type of *P. vetustus* as follows: anterior cingulum of $P\underline{4}$ less expanded; hypocones more prominent. Slight differences may exist in the proportions of the teeth. Lastly, the structure of the protoloph and metaloph, particularly the latter, probably presents points of contrast, but the worn teeth of No. 2150 do not permit comparison. So far as the above distinctions are concerned, *Paramys tricus* could be related to *Prosciurus. Prosciurus vetustus* is known only by the upper dentition. However, *P. relictus* of the middle Oligocene is little

[16] W. B. Scott, Trans. Amer. Philos. Soc., n. s., vol. 16, pt. 3, pp. 475–477, 1889.

[17] R. W. Wilson, *op. cit.,* p. 455, 1937.

[18] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 19, art. 6, pp. 213–215, 1903. A. E. Wood, Trans. Amer. Philos. Soc., n. s., vol. 28, pt. 2, pp. 161–168, 1937.

different in character from the type species,[19] and the lower dentition of this form is quite distinct generically from that of *Paramys tricus*. Differences are numerous and important but need not be listed here. It is hardly possible that the upper and lower dentitions of *P. tricus* are not to be associated, and refer to separate groups.

? *Prosciurus jeffersoni* [20] is a Pipestone Springs species in which the lower dentition is known. This species is larger than *Paramys tricus*, and differs in various other characters, but is closer to it in talonid characters by reason of the incomplete entoconid crests than is *Prosciurus relictus*. Of ? *P. jeffersoni*, Wood states, "The presence of this form in the lowest Oligocene strongly suggests that this is the ancestral stock of the genus, though, of course, it by no means demonstrates it."

Paramys tricus is clearly not closely related to *Prosciurus*. Whether or not it may be a representative of the group from which *Prosciurus* has been derived is perhaps less clear because of the state of wear of the teeth in the Sespe specimens. However, if *Paramys tricus* is near to *P. minutus* in kinship, any connection with the Oligocene genus seems altogether unlikely.

Measurements (in millimeters) of Paramys tricus

	C.I.T. No. 2150
$P\underline{4}$–$M\underline{2}$, anteroposterior length	5.15
$P\underline{3}$–$M\underline{2}$, alveolar length	6.1
$P\underline{4}$, anteroposterior diameter	1.6
$P\underline{4}$, greatest transverse diameter	2.0
$M\underline{1}$, anteroposterior diameter	1.75
$M\underline{1}$, greatest transverse diameter	2.15
$M\underline{2}$, anteroposterior diameter	1.8
$M\underline{2}$, greatest transverse diameter	2.2

	C.I.T. No. 1122 Type specimen
$\overline{I}$–$P\overline{4}$, length of diastema	3.7
$P\overline{4}$–$M\overline{3}$, anteroposterior length	7.85
$P\overline{4}$, anteroposterior diameter	1.8
$P\overline{4}$, greatest transverse diameter	1.8
$M\overline{1}$, anteroposterior diameter	1.8
$M\overline{1}$, greatest transverse diameter	1.95
$M\overline{2}$, anteroposterior diameter	1.9
$M\overline{2}$, greatest transverse diameter	2.1
$M\overline{3}$, anteroposterior diameter	2.3
$M\overline{3}$, greatest transverse diameter	2.0

Paramyid, gen. and sp. indet.

(Plate 1, figure 3)

A much larger paramyid species than *Paramys tricus* is also represented in the collections from locality 150. The known remains are extremely fragmentary, and no generic or specific identification can be made. Included in the material are several detached upper and lower cheek teeth, generally in a worn state or not well preserved, and a right ramus with incisor but without cheek teeth, No. 2151. These specimens vary in size

[19] A. E. Wood, *op. cit.*, pp. 167–169, 1937.

[20] Earl Douglass, Trans. Amer. Philos. Soc., n. s., vol. 20, p. 252, 1901. A. E. Wood, *op. cit.*, p. 172, 1937.

but for the present perhaps should be regarded as representing one species.

The alveolar length of $P\overline{4}$–$M\overline{3}$ is 19 mm. The mandibular incisor is moderately narrow, and its anterior face is rounded. The masseteric fossa extends to beneath the anterior border of $M\overline{2}$. The lower cheek teeth are characterized by rather low trigonids with well-developed anterior cingula but with metalophulid II weak or absent, rather deeply infolded ectolophids without distinct mesoconids, and weak entoconids. The cheek teeth are moderate in width, and a comparatively small $M\overline{3}$, No. 2152, if properly associated with the other material, indicates a species with relatively long and narrow third molars. Little can be said concerning the upper cheek teeth, but the species may be characterized possibly by low lophs. One tooth, No. 2153, is coated heavily in places with a cementlike substance.

Some of the specimens, at least, fall within the size range of *Ischyrotomus* (?) *tapensis*, n. sp. from locality 180. One of the better-preserved lower cheek teeth, No. 2154, also resembles *I.* (?) *tapensis* in some other characters but has a less wide trigonid, and possibly less prominent entoconid. The average size is less than for average *I.* (?) *tapensis*.

Leptotomus kayi [21] of the Duchesne River horizon of the Rocky Mountains area is the only known paramyid (aside from the much smaller *Paramys tricus*) from a comparable geologic stage. The locality 150 species is smaller than *L. kayi*, and does not have the well-developed anterior cingula in the upper cheek teeth of the latter. The present material probably represents an undescribed species, but the remains are not adequate for a determination beyond that given it.

Quarry 180: Upper Eocene

Ischyrotomus (?) tapensis, n. sp.

(Plate 1, figures 4–9*a*)

Type specimen. C.I.T. No. 2157, a right ramus with $P\overline{4}$–$M\overline{3}$.

Referred specimens. C.I.T. No. 2158, posterior part of right ramus with well-worn $M\overline{1}$–$M\overline{3}$; Nos. 2159 to 2168, upper and lower cheek teeth, fragments of incisors.

Geologic age and locality. Upper Eocene; Sespe beds north of Simi Valley, Ventura County, California. C.I.T. Vert. Pale. Loc. 180.

Specific characters. $P\overline{4}$ slightly smaller than $M\overline{1}$, somewhat oval in outline, not triangular. Lower molars of medium width. $M\overline{3}$ relatively long. Ectolophid without mesoconid. Trigonids relatively wide. Entoconid not especially prominent. Enamel only slightly wrinkled. Size about as in *Paramys compressidens*, probably averaging somewhat larger.

Description

The following description emphasizes the principal features of the dentition of this species, and amplifies the specific diagnosis.

The lower incisors are apparently moderately narrow, and somewhat flattened anteriorly. The enamel of the cheek teeth is usually only slightly rugose, and wrinkling disappears with moderate wear. Heavy wrinkling of the type seen in *Leptotomus burkei*, n. sp. is not present. $P\overline{4}$ is slightly smaller than $M\overline{1}$. This tooth is somewhat oval in outline and thus departs in shape from the triangular type seen in *Ischyrotomus petersoni* [22] and

[21] J. J. Burke, Ann. Carnegie Mus., vol. 23, pp. 391–393, 1934.

[22] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 28, art. 6, pp. 56–57, 1910.

I. eugenei.[23] The lower molars are of medium width but with relatively wide and massive trigonids. The width of the trigonid is often greater than that of the talonid. $M\bar{3}$ is relatively long in comparison with that in *P. compressidens* and *I. eugenei*. Cheek-tooth cusps in *I.* (?) *tapensis* are relatively plump. The entoconid is not very prominent, noticeably less so than that in *L. burkei*, n. sp. The internal exits of the basins are reduced to rather slitlike apertures in several of the specimens, and are narrow in all. The posterolophid is of normal appearance, being neither angulate nor especially prominent and distinct from the entoconid as in *Leptotomus leptodus*.[24] The ectolophid is not especially well developed and disappears or becomes poorly defined with wear. In unworn specimens it is a moderate ridge without distinct mesoconid. The upper dentition is known only by detached teeth, or well-worn teeth in bone. Mesostyles are present but these structures are small. The protoconules are usually indistinct or absent, and the metacones usually larger than the metaconules. There is some variation in size. The type is comparable to *P. compressidens*[25] in character of size. It is smaller than *L. leptodus*, but individual specimens of the Sespe species surpass the latter in size.

Comparisons

Paramys compressidens, *Paramys medius*,[26] *Leptotomus leptodus*, and *Paramys uintensis*[27] probably more closely resemble *Ischyrotomus* (?) *tapensis* in size than do other species of "*Paramys*" from the Uinta series. *Paramys compressidens* is close to the Sespe species in several characters but apparently differs in the following characters: (1) somewhat smaller size than average *I.* (?) *tapensis;* (2) $M\bar{3}$ relatively shorter; (3) ectolophid a more pronounced ridge; (4) lower incisor wider; (5) trigonids of molars probably relatively narrower in respect to talonids; (6) entoconids apparently more distinct from posterolophids; and (7) the worn enamel of the cheek teeth still shows some evidence of the coarse wrinkling seen in *Leptotomus burkei*, n. sp. There are no referred upper molars of *P. compressidens*. Conversely, *P. medius* is known only by the type upper molars. Hence, comparison of this species with *I.* (?) *tapensis* is not very satisfactory, since the upper dentition of the latter consists chiefly of isolated teeth mostly of uncertain position in the maxillary, and in some cases of uncertain reference to the Sespe species. *Paramys medius* apparently differs in slightly smaller size than average *I.* (?) *tapensis*, more pronounced wrinkling of the enamel, and more prominent mesostyles. J. W. Gidley, in notes to Peterson's description of *P. compressidens* and *P. medius*, has suggested that these two species should be referred to separate genera, namely to *Ischyrotomus* and *Paramys* respectively. However, the two species are comparable in size, geologic age, and locality, and may possibly be conspecific. The chief reason for regarding them as separate lies, perhaps, in the fact that *P. medius* exhibits a greater degree of resemblance to *P. delicatus*. The character of rugosity mentioned by Gidley is of uncertain value. The type and only specimen

[23] J. J. Burke, Ann. Carnegie Mus., vol. 25, pp. 5–7, 1935.

[24] E. D. Cope, Paleontol. Bull., no. 12, p. 3, 1873. W. D. Matthew, *op. cit.*, p. 56, 1910.

[25] O. A. Peterson, Ann. Carnegie Mus., vol. 12, nos. 2–4, pp. 60–61, 1919.

[26] *Ibid.*, pp. 61–62, 1919.

[27] H. F. Osborn, Bull. Amer. Mus. Nat. Hist., vol. 7, p. 81, 1895. W. D. Matthew, *op. cit.*, p. 56, 1910.

of *P. compressidens* shows remnants of coarse wrinkling. The wrinkling of the type of *P. medius* is of a finer nature. However, in *P. delicatus* mandibular cheek teeth, the fine rugosity is reduced with wear, in some cases at least, to a point where only the heavier wrinkles are evident.

Paramys uintensis is represented by fragmentary material comprising $M\underline{1}$–$M\underline{2}$, $M\underline{2}$, and an incomplete incisor. According to Matthew this material is comparable in character to *Paramys robustus* Marsh.[28] The lower molars of *I.* (?) *tapensis* are apparently narrower, and have less marginal and more distinct entoconids.

Leptotomus leptodus is not close to *I.* (?) *tapensis* except in size. It is distinguished by those characters present generally in *Leptotomus*, namely, (1) better definition of ectolophid; (2) entoconids more prominent and more distinctly separated from posterolophids; (3) higher cusps, internal exit of basin less sharply V-shaped; (4) $P\bar{4}$ relatively larger, more lobate; and (5) trigonids typically narrower.

Ischyrotomus petersoni, type species of the genus *Ischyrotomus*, is larger than *I.* (?) *tapensis*, and has broader molar teeth. However, *I.* (?) *tapensis* bears a resemblance to *I. petersoni* in character of the ectolophid; relatively smooth enamel (upon little wear); a narrow exit to basins of molars; plump and relatively low cusps; and relatively small, although not triangular, $P\bar{4}$.

Among Bridger species, *Paramys delicatus* specimens approach small individuals of *I.* (?) *tapensis* in size. The principal characters separating the Sespe species from *Paramys* (*s. s.*) are: (1) trigonids relatively wider; (2) enamel of cheek teeth much less wrinkled; (3) ectolophid without mesoconid; and (4) $P\bar{4}$ more reduced. *Paramys robustus* Marsh has been referred to both the *Pseudotomus hians* and *Ischyrotomus* groups of Matthew. The Sespe species possesses smaller and narrower molars than the type of *P. robustus*.

Relationships

If to the typical species of *Ischyrotomus* those referred by Peterson and Hay[29] are added, it seems that *I.* (?) *tapensis* should also be referred to this genus. However, *P. compressidens*, *I. gidleyi*, and *I.* (?) *tapensis* are characterized by relatively narrow molars, whereas the other species have relatively wide molars. Matthew and Burke[30] have stressed the terrestrial and fossorial adaptations of the *P. hians-Ischyrotomus* group as opposed to the arboreal habitat of other paramyids. Those species which lend support to this view have broad molars. In any case, this character seems more important in determining the species to be assigned to the group than other characters cited by Gidley in his notes to Peterson's paper of 1919. Thus, in view of the relatively narrow molars in *I.* (?) *tapensis*, assignment of this species to *Ischyrotomus* is a very doubtful procedure. However, in characters other than molar breadth, and possibly width of lower incisor, the Sespe species is closer to *Ischyrotomus* than to *Leptotomus* and *Paramys*. Even in the former character some approach is made to that feature in *Ischyrotomus*, since the trigonids of the molars are relatively broad. Hence, because allocation of *I.* (?) *tapensis* to any other known genus seems even more dubious, the Sespe species is referred questionably

[28] O. C. Marsh, Amer. Jour. Sci., ser. 3, vol. 4, pp. 218–219, 1872. W. D. Matthew, *op. cit.*, pp. 54–55, 1910.

[29] O. A. Peterson, *op. cit.*, p. 63, 1919. O. P. Hay, Carnegie Inst. Wash. Pub. No. 390, vol. 2, p. 903, 1930.

[30] W. D. Matthew, *op. cit.*, p. 57, 1910. J. J. Burke, Ann. Carnegie Mus., vol. 25, p. 147, 1936.

to *Ischyrotomus*. An alternative arrangement would be to assign the species to *Paramys* (*s. l.*), but perhaps this is less satisfactory.

Measurements (in millimeters) of Ischyrotomus (?) tapensis

	C.I.T. No. 2157 Type specimen	C.I.T. No. 2158
Depth of ramus below $M\underline{2}$	....	13.0
$P\underline{4}$–$M\underline{3}$, anteroposterior length	19.7	....
$M\underline{1}$–$M\underline{3}$, anteroposterior length	14.8	16.4
$P\underline{4}$, anteroposterior diameter	4.8	....
$P\underline{4}$, transverse diameter	4.15	....
$M\underline{1}$, anteroposterior diameter	4.6	5.3
$M\underline{1}$, transverse diameter	4.4	4.65
$M\underline{2}$, anteroposterior diameter	4.7	5.0
$M\underline{2}$, transverse diameter	4.7 *	4.9
$M\underline{3}$, anteroposterior diameter	5.5	5.7
$M\underline{3}$, transverse diameter	4.65	4.7

* Estimated.

Paramys cf. **minutus** Wilson

(Plate 1, figures 10, 11)

Among the specimens from locality 180 are two small isolated cheek teeth, a right $M\underline{2}$?, No. 2155, and a right $M\underline{2}$, No. 2156, of a paramyid rodent, which are close in characters to those of *Paramys minutus* from the Bridger deposits. The lower cheek tooth is somewhat larger and relatively broader transversely than similar teeth of *P. minutus* but otherwise is very close. Comparisons of the upper cheek tooth with the cheek teeth of *P. minutus* are handicapped by lack of comparable material. In this regard, the closest Bridger specimen is a referred $M\underline{1}$?. The position of individual teeth in the jaw, and individual variation, probably would account for most if not all of the differences noted below. The two specimens are about equal in size, but: (1) the locality 180 specimen is narrower anteroposteriorly; (2) the hypocone in our form may be slightly better developed and this cusp more nearly on a line with the protocone than in the Bridger species, in which it is more external in position; (3) *P.* cf. *minutus* is without a mesostyle, and cross-crests are more subdued.

Geologic age difference and geographical separation suggest that the Californian specimens represent a distinct species, but this is not demonstrated by existing material. The relation of *Paramys* cf. *minutus* to *Paramys tricus* has been discussed under the description of the latter species. As indicated there, the locality 180 species may be ancestral to the locality 150 type.

Paramyid, spp. div.

In addition to specimens representing *Ischyrotomus* (?) *tapensis* and *Paramys* cf. *minutus*, there are a number of isolated lower teeth and a fragment of ramus with $P\underline{4}$ and $M\underline{2}$, No. 2169, which apparently represent a third quarry species. This species is somewhat smaller than *I.* (?) *tapensis*. The lower dentition is narrower, with more prominent entoconids and slightly angulate posterolophids. The inner cusps may be higher. This species approaches members of the *Leptotomus* group in characters, but the fragmentary remains make comparisons of small value. Also present are isolated upper cheek teeth, distinct from those referred to *I.* (?) *tapensis*, some of which, at least, presumably belong to this third species.

Individual teeth are encountered at locality 180 which somewhat resemble *Leptotomus* (?) *caryophilus*, n. sp. from the Poway conglomerate except for size, and one large lower tooth, No. 2170, is rather close in characters, including size, to *L. leptodus* and *L. burkei*, n. sp. However, any close agreement of specimens from locality 180 with specimens from other Californian localities is rare, and specific differences are apparently always present.

Quarry 202: Upper Eocene

Leptotomus burkei,[31] n. sp.

(Plate 2, figures 1, 1*a*)

Type specimen. C.I.T. No. 2172, incomplete right ramus with $M\bar{1}$–$M\bar{3}$.

Referred specimens. C.I.T. No. 2173, fragmentary right ramus with $M\bar{1}$–$M\bar{3}$; C.I.T. No. 2174, fragmentary left ramus with well-worn and incomplete $P\bar{4}$–$M\bar{2}$; and C.I.T. No. 2175, left upper incisor.

Geologic age and locality. Upper Eocene; deposits north of Simi Valley, Ventura County, California. C.I.T. Vert. Pale. Loc. 202.

Specific characters. Ramus relatively shallow. Enamel of cheek teeth coarsely wrinkled. Trigonid of $M\bar{1}$ relatively wide. Mesoconids are prominent elements of the ectolophids. $M\bar{3}$ long, posterolophid not pointed, and entoconid rather posterior in position. Size as in *Leptotomus grangeri*, larger than in *L. leptodus*.

Discussion

Leptotomus burkei is closely related to *L. grangeri*,[32] *L. leptodus*, and apparently also *L.* (?) *robustus* (*Prosciurus* [?] *robustus*), upper Eocene species from the Uinta and upper Washakie. The new species agrees with *L. grangeri* in size but comparison with the Uinta species suggests the following differences: (1) cheek-tooth enamel of *L. burkei* rather coarsely wrinkled, smooth in *L. grangeri;* (2) mesoconid a more prominent element of ectolophid in *L. burkei;* (3) ramus shallower; (4) trigonid of $M\bar{1}$ may be broader, relative to talonid; and (5) $M\bar{3}$ of *L. burkei* apparently longer, entoconid more posterior in position, lacks the pointed posterior termination of the Uinta form. However, it should be noted in respect to the characters in $M\bar{3}$ (5) that this tooth in the type of *L. grangeri* has been cracked and fragments of the talonid displaced. This circumstance makes the features noted somewhat uncertain. Also, the teeth of the type of *L. grangeri* are more heavily worn than in either No. 2172 or No. 2173, and such a character as (1) may be materially affected by wear.

Leptotomus burkei is distinguished from the type of *L. leptodus* by: (1) larger size; and (2) entoconid less distinctly separated from posterolophid. A somewhat more complex cheek-tooth pattern in *L. burkei* is due to the (apparent) absence in *L. leptodus* of some of the minor spurs formed by the coarse wrinkling of enamel in the former. The cheek-tooth enamel is wrinkled in both types. Molar proportions are similar except that $M\bar{1}$ in *L. burkei* may be slightly broader. Development of the ectolophid in the Sespe species agrees more closely with *L. leptodus* than with *L. grangeri*. No. 2172 has small metastylids in the molars, and such cuspules are absent in both *L. leptodus* and *L. grangeri*, but are present in *L.* (?) *robustus*. However, these structures are also absent in No. 2173 and appear to be individual in character.

[31] Named in honor of Mr. John J. Burke in recognition of his work on fossil rodents.

[32] W. D. Matthew, *op. cit.*, pp. 57, 59, 1910.

Leptotomus (?) *robustus* of the Uinta is probably a member of the *Leptotomus* group. The type is a fragment of ramus with M3. This tooth is larger than M3 in *L. burkei*, but relatively slightly broader, and the ectolophid is somewhat more continuous. Wrinkling of the enamel in the central basin is coarser and deeper. Paratype specimen No. 2926, a fragment of ramus with M2, has a narrower molar than *L. burkei*, and apparently also possesses a more continuous ectolophid and deeper wrinkling of the enamel. Type and paratype of *L.* (?) *robustus* differ considerably in size. If these two specimens are conspecific, our species is certainly closely related, but may be distinguished by the lighter wrinkling of enamel, more interrupted and cuspate ectolophid, and wider M2.

Leptotomus kayi is from the Duchesne River series, and hence is of younger geologic age than *L. burkei*. The only known material consists of a maxillary with worn P4–M3. The upper cheek tooth of *L.* near *burkei* from locality 207 is much less worn and comparisons are difficult. The anterior cingulum in *L. kayi* may be broader anteroposteriorly, but conclusive differences are not readily observable. No comparable specimens have been found at the type locality of *L. burkei*.

Leptotomus burkei is apparently a descendant of the *Paramys delicatus* group. Among upper Eocene species, it is allied closely to *L. grangeri* and *L. leptodus*. Perhaps a nearer relationship to *L.* (?) *robustus* should be stressed, but the material representing Peterson's species is too fragmentary to justify such a conclusion. The comparative characters mentioned for *L. burkei* are not altogether satisfying, since individual variation may affect them to some extent. However, when all due allowances are made, it still seems desirable to recognize the Sespe type as a distinct species. Geographic separation lessens the possibility of specific identity.

Measurements (in millimeters) of Leptotomus burkei

	C.I.T. No. 2172	C.I.T. No. 2173
Depth of ramus below M2	11.1	....
Thickness of ramus below M2	6.5	....
M1–M3, anteroposterior length	17.3	17.3
M1, anteroposterior diameter	5.15	5.4
M1, greatest transverse diameter	5.15	5.1
M2, anteroposterior diameter	5.15	5.2
M2, greatest transverse diameter	5.0	5.1
M3, anteroposterior diameter	6.6	6.5
M3, greatest transverse diameter	4.8	4.7

Quarry 207: Upper Eocene

Rapamys fricki,[33] n. gen. and sp.

(Plate 2, figures 4–5*a*)

Type specimen. C.I.T. No. 2181, an incomplete mandible with left P4–M3 and right P4–M2.

Referred specimens. C.I.T. No. 2183, a fragmentary right maxillary with P4–M3; and C.I.T. No. 2184, a fragmentary right maxillary with P4, M2, and incomplete M3.

Geologic age and locality. Upper Eocene; Sespe deposits north of Simi Valley, Ventura County, California. C.I.T. Vert. Pale. Loc. 207.

[33] This species is named in honor of Mr. Childs Frick in recognition of his contributions to vertebrate paleontology. The generic name is an anagram of *Paramys*.

Generic and specific characters. Upper molars relatively quadrate, P4 subcircular, rather small. Protoloph low and weak without distinct cusps. Metacone smaller than metaconule, the former divided in M1 and M2 into distinct cuspules. Mandibular incisor of medium width with convex enamel band. Enamel of cheek teeth only slightly wrinkled. P4 and M1 subequal in size. Lower molars of average breadth. Ectolophid rather deeply infolded without mesoconid. Short metalophulid II spur present. Entoconids robust, oriented more transversely than in other paramyids. Posterolophids angulate and prominent, relatively short, and distinctly set off from entoconids. Size about as in *Paramys delicatior*.

Description

Superior dentition. P4 of No. 2183 is a subcircular tooth, somewhat pointed internally. The tooth is broken in the protocone region but there is no evidence of an incipient hypocone, a statement verified by P4 of No. 2184. The protoloph is low and poorly defined. The cusps which make up this loph are not distinct, but the external or paracone portion is somewhat triangular in shape. A small protoconule may be present, but if so is very indistinct. The metacone is an irregular cusp which exhibits evidence of division into two cuspules, a feature more clearly seen in M1. The metaconule is broadly united to the metacone, and is distinctly larger than the latter. The metacone is separated from the external border of the tooth by a raised cingulum and intervening depression. No mesostyle is visible. P4 of No. 2184 is more worn than that of No. 2183 but apparently presents some points of difference. The tooth is longer transversely, the paracone is much more prominent, and the portion of the cingulum opposite the metacone is produced into a distinct cuspule.

The succeeding molars are more quadrate in outline and are larger than the premolar. M1 has an incipient hypocone which is rather distinctly demarcated from the protocone. As in P4, the protoloph is low and weak with poorly defined cusps. The paracone cusp is also triangular, but more distinct. A small and not too distinct protoconule appears to be present. Metacone and metaconule are rather sharply separated. The former is smaller and is, moreover, divided near its apex into two obliquely set cuspules. A portion of the cingulum projects as a short spur into the valley between paracone and anterior cingulum. A relatively large mesostyle is present, but this cuspule is not very distinct from the external cingulum.

M2 is comparable to M1 except that the protoconule is not distinct from the protoloph, which is somewhat more strongly crested than in M1, and the metacone consists of one relatively large external cuspule and two internal ones.

The protoloph of M3 is similar to that of M2. The posterior margin of the tooth is raised into a series of tiny cuspules but no distinct hypocone is present. A small cusp, apparently the metaconule, is present in the basin of the tooth, and a weak crest runs from this cusp to the posterior margin of M3.

It is fairly certain that the upper dentitions represented by Nos. 2183 and 2184 are conspecific with the type of *Rapamys fricki*. Reasons for assigning this material to *R. fricki* are: (1) occlusion of upper and lower dentitions is as good as can be expected with the present fragmentary material; (2) the only other paramyid specimens from quarry 207 belong to larger and otherwise distinct species.

Inferior dentition. The mandibular incisor is of medium width with convex enamel band. The cheek teeth are of average breadth. P4 and M1

are subequal in size, but the former tooth has a narrower trigonid. The trigonids of both $P\bar{4}$ and $M\bar{1}$ are narrow in comparison with that of $M\bar{2}$. The enamel of the cheek teeth of *Rapamys* is slightly wrinkled, but this character is not marked. Metastylids are absent. Entoconids are relatively anterior in position.

The protoconid of $P\bar{4}$ is well developed. A slight metalophulid II crest unites this cusp with the metaconid. The ectolophid is well defined and rather deeply infolded, and is without a mesoconid. The posterolophid proper or hypoconulid (?) is separated from the hypoconid by a slight angulation of the crest resulting from a constriction of the posterolophid at this point. It is somewhat longer than the same structure in the molars. Internally, it unites with the entoconid but only at the base of the cusp. Hence, there is a slight valley separating the posterolophid from the entoconid.

$M\bar{1}$ is in general similar to $P\bar{4}$ but with wider trigonid, more angulate and cuspate posterolophid, and more robust entoconid. Metalophulid II is a stubby spur directed posterointernally, and does not reach the metaconid proper. The pattern of $M\bar{2}$ is essentially as in $M\bar{1}$.

$M\bar{3}$ is more nearly a typical paramyid tooth. The entoconid, however, is well separated from the posterolophid, although less so than in the preceding molars. Posterolophid and hypoconid form a more continuous curving crest than in the other molars. The ectolophid is slightly more cuspate. $M\bar{3}$ is long.

Discussion

The principal characters of the new genus lie in the talonids of the cheek teeth. In typical paramyids, the posterior borders of the teeth form continuous, curving crests from hypoconid to entoconid. The entoconid is never separated from the posterolophid by more than a slight notch, although the apex of the cusp may rise considerably above the posterolophid. This cusp is always more or less marginal, and is oriented parallel to the tooth border. In *Rapamys*, the entoconid is robust and is markedly separated from the posterolophid. It is much less marginal than in typical members of the group, and has a transverse rather than anteroposterior orientation. A shallow but distinct valley separates it from the posterolophid. The posterolophid is also distinctive in being relatively cuspate, and entirely transverse except for the point of union with the hypoconid, where, in consequence of its position in back of the hypoconid, the crest is conspicuously angulate. The slope of the posterolophid from the external border of the hypoconid to its terminus is more or less continuously downward. This condition is seen in the sciuravids, but usually in paramyids the hypoconulid portion of the crest is relatively horizontal. The feature probably is due more or less to wear, but it serves to emphasize the somewhat different cusp-crest relation in the new genus. In those characters of the heel region in which *Rapamys* departs from the normal paramyid structure, the genus parallels the sciuravids without, however, producing a comparable degree of cresting in the molar cusps.

Some paramyids, apparently representing the genus *Leptotomus*, approach but do not duplicate *Rapamys* in construction of the talonids. Since these are essentially contemporaneous with the Sespe genus, they are not ancestral but do indicate the close affinities of *Rapamys* with typical paramyids—a conclusion also clearly demonstrated by the general structure of the lower molars, and by the referred upper dentition.[34]

[34] It appears probable that various later Eocene forms (*Rapamys*, *Eohaplomys*, and possibly others) developed within the paramyid group or closely related thereto, which

In addition to the type dentition, an isolated $P\underline{4}$, No. 2182, from locality 207, although more deeply worn than $P\underline{4}$ of the holotype, shows essentially the same pattern. This additional specimen emphasizes the fact, if this is necessary, that No. 2181 can be considered a normal specimen, and its characters are not merely the result of abnormal development.

Apparently no other known species of *"Paramys"* is sufficiently close to *Rapamys fricki* to be considered congeneric.

Measurements (in millimeters) of Rapamys fricki	C.I.T. No. 2183
$P\underline{4}$–$M\underline{3}$, anteroposterior length	15.9*
$P\underline{4}$, anteroposterior diameter	3.5
$P\underline{4}$, greatest transverse diameter	3.9
$M\underline{1}$, anteroposterior diameter	3.8
$M\underline{1}$, greatest transverse diameter	4.2†
$M\underline{2}$, anteroposterior diameter	4.0
$M\underline{2}$, greatest transverse diameter	4.1
$M\underline{3}$, anteroposterior diameter	4.2
$M\underline{3}$, greatest transverse diameter	4.0

	C.I.T. No. 2181 Holotype, left ramus
$P\bar{4}$–$M\bar{3}$, anteroposterior length (alveolar)	17.5‡
$P\bar{4}$–$M\bar{3}$, anteroposterior length	16.7*
$P\bar{4}$, anteroposterior diameter	3.7
$P\bar{4}$, greatest transverse diameter	3.6+
$M\bar{1}$, anteroposterior diameter	3.7
$M\bar{1}$, greatest transverse diameter	3.7
$M\bar{2}$, anteroposterior diameter	3.95
$M\bar{2}$, greatest transverse diameter	3.8
$M\bar{3}$, anteroposterior diameter	4.6(?)
$M\bar{3}$, greatest transverse diameter	3.6

* Teeth spread out of normal contact.
† Structure of these teeth makes accurate transverse measurements extremely difficult.
‡ Estimated.

Leptotomus near **burkei** Wilson

(Plate 2, figures 2, 3)

Rodent material from locality 207 which has been assigned to *Leptotomus* near *burkei* is very fragmentary. It consists of three isolated cheek teeth, Nos. 2176 to 2178 ($P\bar{4}$, $M\bar{1}$ or $M\bar{2}$, and an upper molar), and fragments of incisors, No. 2179. Since this locality is some 75 feet lower stratigraphically than the quarry yielding the type remains, some doubt may exist as to the

had entoconid-posterolophid relations suggestive of those for *Mysops* and *Sciuravus* without being in or near the line of descent of these genera. Consequently, it is possible, if not probable, that the dentition of the Oligocene genus *Prosciurus* has been derived directly from a paramyid pattern without passing through a "sciuravid" stage. In other words, the similarity of *Prosciurus* to the "sciuravids" may be the result largely of parallelism, and pre-Oligocene prosciurids may have converged regressively toward the paramyids and diverged from the contemporary sciuravids and ischyromyids. A. E. Wood (Trans. Amer. Philos. Soc., n. s., vol. 28, pt. 2, p. 172, 1937) has pointed out essentially the same possibility in considering the relations of *Prosciurus*. Perhaps *Rapamys* should be given consideration as a possible representative of a pre-Oligocene prosciurid stock.

These remarks should not be construed as serious convictions of the present author. However, they represent an alternative view of the relationships of some Eocene-Oligocene rodents, and perhaps are worthy of consideration.

specific identity of specimens from the two localities. However, at present there is no real reason for regarding the geologically older specimens as distinct.

Leptotomus sp.

(Plate 1, figure 12)

A specimen from locality 207, No. 2180, a fragmentary left ramus with $P\bar{4}$–$M\bar{1}$, may also be referable to the genus *Leptotomus*. The dentition is distinctly smaller than that of *Leptotomus burkei*. The cheek teeth are slight in respect to the fragment of ramus preserved. Crushing has served to distort the original shape and size of the jaw, but apparently the jaw was comparable in this regard to that in *L. burkei*. No. 2180 cannot be assigned to the species *L. burkei*, but the specimen is too fragmentary to be used as a basis for a distinct species. The generic determination is tentative but No. 2180 certainly does not represent an *Ischyrotomus*, and average specimens of *Paramys delicatus* have relatively larger premolars.

Measurements (in millimeters) of Leptotomus sp.

	C.I.T. No. 2180
Depth of ramus below $M\bar{2}$	11.45(?)
$P\bar{4}$–$M\bar{1}$, anteroposterior length	9.3
$P\bar{4}$, anteroposterior diameter	4.7
$P\bar{4}$, greatest transverse diameter	4.3
$M\bar{1}$, anteroposterior diameter	4.5
$M\bar{1}$, greatest transverse diameter	4.4

Quarry 249: Upper (?) Eocene

Ischyrotomus californicus, n. sp.

(Plate 2, figures 6, 7)

Type specimen. C.I.T. No. 2185, fragmentary right ramus with $P\bar{4}$–$M\bar{3}$.

Referred specimens. C.I.T. No. 2186, poorly preserved fragment of right ramus with $M\bar{1}$–$M\bar{2}$ and incomplete $\bar{I}$; and C.I.T. No. 2187, left upper cheek tooth.

Geologic age and locality. Upper (?) Eocene; sandstones of the Poway conglomerate, exposed in west bank of the San Diego River, approximately one-quarter mile north and east of the Mission San Diego. C.I.T. Vert. Pale. Loc. 249.

Specific characters. Anterior face of lower incisor flat (?). Anterior cheek teeth wide transversely, but $M\bar{3}$ long. $P\bar{4}$ about equal in size to $M\bar{1}$, not right-triangular in outline. Internal exits of basins relatively wide. Size comparable to that of *Ischyrotomus petersoni*.

Description

Ischyrotomus californicus is comparable in size to *I. petersoni*. The masseteric fossa, as observed in referred specimen No. 2186, ends beneath the anterior and posterior borders of $M\bar{2}$ and $M\bar{1}$ respectively, but essentially beneath $M\bar{2}$.

The type specimen does not retain the lower incisor, but No. 2186 has an incomplete one which is moderately wide with flat anterior face. Flattening of the incisor is rather rare among known paramyids but is recorded for *Ischyrotomus petersoni* and *I. eugenei*. An isolated incisor, No. 2188,

presumably a lower, is also present in the collections which, although of nearly the same size as that in No. 2186, has a slightly convex enamel band. Since there is no other species present at locality 249 to which this second incisor can be referred at present, the character of the enamel face may be variable. However, until definite evidence is available, it may be assumed tentatively that the incisor in *I. californicus* is flattened.

The cheek teeth in *Ischyrotomus californicus* are wide transversely with the exception of $M\bar{3}$, which is long. In character of width of the anterior grinders, the Poway species resembles comparable teeth of *I. petersoni*, *I. eugenei*, and *"Paramys" robustus* Marsh, but $M\bar{3}$ appears to be longer. The third molar is the only cheek tooth of *I. californicus* in which length exceeds breadth. $P\bar{4}$ and $M\bar{1}$ are subequal in size. $M\bar{2}$ is somewhat larger than the preceding teeth, and $M\bar{3}$, although slightly narrower, is much longer (see measurements). Some evidence is still preserved in the worn teeth of apparently coarse wrinkling of enamel.

The anterior portion of $P\bar{4}$ is somewhat damaged but the tooth lacks the right-triangular outlines seen in *I. eugenei* and *I. petersoni*. $P\bar{4}$ is peculiar in having the protoconid, which is moderately distinct, set in from the anteroexternal buttress with a distinct ledge at the anteroexternal margin of the tooth.

The cheek teeth apparently have mesoconids, but characters in the ectolophid region are indistinct. The exits of the basins internally are not noticeably narrowed. In the present stage of wear, entoconids are not prominent, and all cusps are relatively low.

A single left upper molar of *Ischyrotomus californicus*, possibly representing an $M\bar{2}$, No. 2187, is present in the collections. Cresting of the lophs is not marked. The cuspate metaconule is equal to and probably larger than the metacone. A small but distinct protoconule is present, as is a mesostyle. There is a very slight development of a hypocone. The enamel exhibits evidence of wrinkling.

Comparisons

In general characters, *Ischyrotomus californicus* is closer to *I. petersoni*, *I. eugenei*, and *"Paramys" robustus* than to other paramyids. Compared with the Uinta (Wagonhound or Uinta B) species, *I. petersoni*, the Californian type differs in: (1) less triangular $P\bar{4}$, perhaps less reduced; (2) longer $M\bar{3}$; and (3) wider internal exits of basins. *Ischyrotomus californicus* is comparable in size but is probably slightly larger.

Ischyrotomus eugenei (Myton or Uinta C) is much larger than *I. californicus*, with relatively shorter $M\bar{3}$ and more triangular $P\bar{4}$.

The type of *"Paramys" robustus* Marsh of the lower Bridger consists of two isolated teeth, $M\bar{2}$ and $M\bar{3}$. This material is hardly adequate for comparisons, but its older geologic age indicates a species distinct from the Californian one. Several Bridger specimens in the American Museum of Natural History collections have been referred to *"P." robustus* by Matthew. *Ischyrotomus californicus*, although of comparable size, is distinguished from this material by: (1) longer $M\bar{3}$; (2) lower incisor with flat (?) anterior face, rounded in Bridger species; (3) $M\bar{1}$ slightly narrower in relation to its length; and (4) $P\bar{4}$ less reduced.

Ischyrotomus californicus is closer possibly to *Paramys* in larger $M\bar{3}$ and less triangular $P\bar{4}$ than are *I. petersoni* and *I. eugenei*. These characters may indicate a less advanced species.

Measurements (in millimeters) of Ischyrotomus californicus

	C.I.T. No. 2185 Type specimen
P$\underline{4}$–M$\underline{3}$, estimated alveolar length	24.8
P$\underline{4}$–M$\underline{3}$, estimated anteroposterior length	24.2
M$\underline{1}$–M$\underline{3}$, anteroposterior length	18.5
P$\underline{4}$, anteroposterior diameter	5.5(?)
P$\underline{4}$, greatest transverse diameter	5.9
M$\underline{1}$, anteroposterior diameter	5.4
M$\underline{1}$, greatest transverse diameter	5.9
M$\underline{2}$, anteroposterior diameter	5.5
M$\underline{2}$, greatest transverse diameter	6.4
M$\underline{3}$, anteroposterior diameter	7.2
M$\underline{3}$, greatest transverse diameter	5.8

Leptotomus (?) caryophilus, n. sp.

(Plate 2, figures 8, 9)

Type specimen. C.I.T. No. 2189, left maxillary with P$\underline{4}$–M$\underline{2}$.

Referred specimens. C.I.T. No. 2190, left maxillary with M$\underline{1}$–M$\underline{2}$ and alveoli for P$\underline{3}$–P$\underline{4}$; C.I.T. No. 2191, left M$\underline{1}$–M$\underline{2}$ with fragment of jaw; C.I.T. No. 2192, incomplete right ramus with poorly preserved P$\underline{4}$–M$\underline{2}$; and C.I.T. No. 2193, an unworn lower molar.

Geologic age and locality. Upper (?) Eocene; sandstones of the Poway conglomerate, exposed in west bank of the San Diego River, approximately one-quarter mile north and east of the Mission San Diego. C.I.T. Vert. Pale. Loc. 249.

Specific characters. Enamel of cheek teeth smooth. P$\underline{4}$ relatively large. Protoconule usually distinct. Metaloph crested, metacone-metaconule of molars divided into three transversely oriented cuspules in unworn state. Mesoconid well developed. Size somewhat variable, apparently ranging from comparable to *Paramys delicatior* to nearly as small as *Reithroparamys delicatissimus*.

Description

P$\underline{4}$ is a large tooth, equal in size to the molars. It is subquadrate in outline with prominent cusps. The metaconule is almost as large as the metacone, and the protoconule although small is distinct. The rather low cingula are of about equal strength anteriorly and posteriorly. No hypocone is present.

M$\underline{1}$ and M$\underline{2}$ are more elongate anteroposteriorly than the premolar. This character is due principally to the cingula, which internally exhibit more nearly rectangular outlines. The posterior cingulum is enlarged into more or less of a hypocone, a feature best shown in No. 2190. Protoconules are distinct in No. 2190, but are somewhat obscured by wear in the molars of the type. The metaloph is relatively well crested. In M$\underline{2}$ of No. 2189 and M$\underline{1}$ and M$\underline{2}$ of No. 2190, this metacone-metaconule crest is divided at its summit into three subequal cuspules. M$\underline{1}$ of the former specimen has only the usual two cusps, and probably never possessed the additional one, although surface wear may have obliterated it. Mesostyles are present in the cheek teeth.

An isolated P$\underline{3}$, No. 2199, in the collections probably pertains to *L.* (?) *caryophilus*. The crown is composed of an anteroexternal cusp and a crest posterior to it, which runs diagonally across the surface of the tooth. A small posterointernal cingulum is present.

The remains of ramus and lower dentition are too fragmentary to furnish much information as to characters. The cheek teeth are of moderate width. M$\bar{1}$ and M$\bar{2}$ are subequal in size. P$\bar{4}$ of No. 2192 is incomplete but could hardly have been much, if any, larger than M$\bar{1}$. The alveolar length in this specimen is about 15.5 mm. Distinct mesoconids are present in the cheek teeth. The enamel of the teeth, both upper and lower, is smooth or nearly so.

Comparisons and Relationships

Leptotomus (?) *caryophilus* approaches in size *Ischyrotomus gidleyi*,[35] *Paramys sciuroides* of the Myton (Uinta C), and *Paramys delicatior*,[36] *Reithroparamys delicatissimus* [37] of the Bridger. *Ischyrotomus gidleyi* is known only by a fragment of ramus with M$\bar{1}$–M$\bar{2}$, hence comparisons are limited. However, *L.* (?) *caryophilus* is somewhat larger in size, the enamel appears smoother, the internal exits of the basins are more open, and the mesoconids are not so crested. *Leptotomus* (?) *caryophilus* differs from the second Uinta species, *P. sciuroides*, in: (1) less triangular upper molars; (2) probably somewhat larger size; and (3) probable possession of more prominent protoconules as well as character of the metaloph, judging from description and figures of the Uinta type. The two species agree in having relatively large upper premolars. *Paramys delicatior* is about the size of our species, but may average larger. *Leptotomus* (?) *caryophilus* is readily distinguished by the smooth enamel of the cheek teeth, the enamel in *P. delicatior* being finely rugose, apparently a generic character of *Paramys* (*s. s.*). In addition, the Californian species has more elongate upper molars, and the triple-cusped metacone-metaconule is a feature which has not been observed in *P. delicatior*. Distinguishing characters separating our species from the apparently somewhat smaller *Reithroparamys delicatissimus* are hard to establish on the basis of present descriptions of the dentition of the Bridger species. However, since Matthew stated that no clearly generic differences in the dentition separate *Reithroparamys* from *Paramys*, probably some of the *P. delicatior* characters apply, in addition to size.

Among Sespe types, *Rapamys fricki* is comparable in size to some specimens of *L.* (?) *caryophilus*. However, the two are quite distinct generically. Several upper cheek teeth from Sespe locality 180 have metalophs with the additional cuspule, but these teeth are larger and less elongate, and apparently the enamel is less smooth. One lower cheek tooth (left M$\bar{1}$?), No. 2171, from locality 180 resembles those of *L.* (?) *caryophilus* rather closely but is smaller.[38] These locality 180 specimens may represent possibly related but not identical species.

The present generic assignment of *L.* (?) *caryophilus* to *Leptotomus* is very dubious. However, only *Paramys*, *Reithroparamys*, and *Leptotomus* of the known genera qualify for serious consideration, and the last-mentioned may be the most probable. The characteristic rugosity of enamel in *Paramys* (*s. s.*) is not present in the Poway species, and *L.* (?) *caryophilus* apparently cannot be referred to *Paramys* unless in the older, broader sense. In view of the absence of skull material from the San Diego locality, *Reithroparamys* can hardly be taken into account. On the other hand, several

[35] O. A. Peterson, Ann. Carnegie Mus., vol. 12, nos. 2–4, p. 63, 1919.

[36] J. Leidy, Proc. Acad. Nat. Sci., Phila., p. 231, 1871. W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 28, art. 6, pp. 56–57, 1910.

[37] J. Leidy, *loc. cit.*, 1871. W. D. Matthew, Jour. Mammal., vol. 1, pp. 168–169, 1920.

[38] This specimen is about the size of M$\bar{1}$ in *Ischyrotomus gidleyi* but differs from the Uinta species in less V-shaped notch of internal exit of basin, and lower, perhaps less marginal entoconid.

characters of *L.* (?) *caryophilus* are duplicated in species of *Leptotomus*, and the new species may be placed doubtfully in this genus pending further information.

Measurements (in millimeters) of Leptotomus (?) caryophilus

	C.I.T. No. 2189	C.I.T. No. 2190
$P\underline{4}$–$M\underline{2}$, anteroposterior length	10.1	....
$P\underline{4}$–$M\underline{2}$, alveolar length	....	10.0(?)
$P\underline{4}$, anteroposterior diameter	3.4	....
$P\underline{4}$, greatest transverse width	3.8	....
$M\underline{1}$, anteroposterior diameter	3.2	3.6
$M\underline{1}$, greatest transverse width	4.1	4.2
$M\underline{2}$, anteroposterior diameter	3.6	3.8
$M\underline{2}$, greatest transverse width	3.7	4.1
	C.I.T. No. 2191	C.I.T. No. 2192
$P\bar{4}$–$M\bar{3}$, estimated alveolar length	....	15.5
$M\bar{1}$–$M\bar{2}$, anteroposterior length	7.5	7.2
$P\bar{4}$, anteroposterior diameter	....	3.8
$M\bar{1}$, anteroposterior diameter	3.7	3.5
$M\bar{1}$, greatest transverse width	3.4	3.5
$M\bar{2}$, anteroposterior diameter	3.8	3.7
$M\bar{2}$, greatest transverse width	3.6	3.7 (?)

Paramyid (?), sp. probably new

(Plate 2, figures 10, 10*a*)

An incomplete left ramus with rather worn $M\bar{1}$–$M\bar{3}$, No. 2194, represents a type apparently distinct from other rodent species obtained from the Poway conglomerate. In size, the specimen is comparable to individuals of *Sciuravus nitidus*,[39] and large individuals of a new species of *Sciuravus* from San Diego. It is smaller than any middle or upper Eocene paramyid except *Paramys tricus*, and *minutus*, which is distinctly smaller: $M\bar{1}$–$M\bar{3}$, anteroposterior length, measures 7.0 mm., and length of $P\bar{4}$–$M\bar{3}$ is about 9.0–9.5 mm.

The pattern of the cheek teeth is obscured by wear, but reference to the paramyids is suggested by (1) entoconids apparently marginal, not crested; (2) $M\bar{3}$ relatively large, larger than in either *Sciuravus nitidus* or the Poway *Sciuravus;* and (3) masseteric fossa terminates anteriorly beneath contact of $M\bar{2}$ and $M\bar{3}$ rather than generally under anterior part of $M\bar{2}$ as in *S. nitidus*, or the posterior part of $M\bar{1}$ as in the Poway *Sciuravus*. On the other hand, sciuravid affinities are suggested by elevation of the trigonids, especially of $M\bar{1}$; better size agreement with *Sciuravus* species than with paramyid types; and character of the posterolophids of $M\bar{1}$ and $M\bar{2}$. Although heavily worn, the posterolophids still retain a decidedly oblique orientation, and may have been distinct from the entoconids. Several other characters are equivocal, and might point equally to sciuravid or paramyid relationships.

The principal reason for assignment of No. 2194 to the paramyids lies in the marginal character of the entoconids. The specimen may belong to the group mentioned under the discussion of *Rapamys fricki*, but the

[39] O. C. Marsh, Amer. Jour. Sci., ser. 3, vol. 2, no. 8, p. 122, 1871. R. W. Wilson, Amer. Jour. Sci., ser. 5, vol. 35, no. 206, pp. 129–133, 1938.

San Diego species is represented by too poor material to warrant speculation on its relationships. In any case, apparently a new species is present.

Paramyid spp.

A right lower molar, No. 2195, represents a tiny paramyid which is distinctly smaller than *Paramys minutus*, and hence presumably the smallest paramyid so far to be put on record. In general, except for size, it is similar to *P. minutus*. A second specimen, No. 2196, comparable in size, may represent a more worn left lower molar of the same species, but several characters are present which make it possible that No. 2196 belongs to a distinct type. The metaconid is slightly more posterior in position and hence more on a line with the protoconid, basining of the crown is less apparent, and the posterolophid is shorter, being demarcated from the entoconid by a slight groove on the posterior wall of the tooth.

An isolated upper molar, No. 2197, comparable in size to the molars of *Leptotomus* (?) *caryophilus* but with more rounded outline, has a pattern differing considerably from that in *L.* (?) *caryophilus*, and deserves mention. No. 2197 disagrees notably in the weakness of the protoconule and especially the metaconule. The latter cuspule is small and low, and consequently the metaloph is very weak. The hypocone is more distinct from the protocone than in *L.* (?) *caryophilus*. While this specimen may be an extreme variant of *L.* (?) *caryophilus*, its characters indicate an entirely different form.

Two heavily worn upper cheek teeth, No. 2198, represent paramyids comparable in size to *Paramys delicatus*. Stage of wear prevents a determination of characters other than size. However, the specimens apparently are distinct from other Poway species.

Key to Recognition of Californian Paramyid Species

I. Size large: $P\overline{4}$–$M\overline{3}$ more than 19.0 mm.
   1. $P\overline{4}$, $M\overline{1}$, and $M\overline{2}$ wider than long.
      Cusps relatively low, entoconids not prominent, mesoconids apparently present but not prominent. Incisor moderately wide, anterior face flat (?). Enamel apparently coarsely wrinkled. *Ischyrotomus californicus*, n. sp.
   2. $P\overline{4}$, $M\overline{1}$, and $M\overline{2}$ longer than wide, or at least of equal dimensions.
      (*a*) $P\overline{4}$ relatively large (?). Entoconids prominent; mesoconids well developed; enamel coarsely wrinkled; size larger. *Leptotomus burkei*, n. sp.
      (*b*) $P\overline{4}$ relatively reduced; entoconids not especially prominent; mesoconids absent; enamel only slightly wrinkled; incisor moderately narrow, somewhat flattened anteriorly; size smaller. *Ischyrotomus* (?) *tapensis*, n. sp.

II. Size medium: $P\overline{4}$–$M\overline{3}$ more than 12.0, less than 18.0 mm.
   1. Posterolophids angulate and prominent, relatively short, distinctly set off from robust entoconids; ectolophids well defined, without mesoconids; $P\underline{4}$ relatively small; protolophs without distinct cusps; enamel slightly wrinkled. *Rapamys fricki*, n. gen. and sp.
   2. Talonids of normal paramyid construction; mesoconids well developed; $P\underline{4}$ relatively large; protoconules of upper cheek teeth usually distinct; enamel smooth. *Leptotomus* (?) *caryophilus*, n. sp.

III. Size small: $P\overline{4}$–$M\overline{3}$ less than 10.0 mm.
   1. Metastylid ridges absent; size larger. *Paramys tricus*, n. sp.
   2. Metastylid ridges present; size smaller. *Paramys* cf. *minutus* Wilson.

Plate 1

Paramys tricus, n. sp.

Figs. 1, 1*a*. Type right ramus with incisor and $P\bar{4}$–$M\bar{3}$, No. 1122, loc. 150. Fig. 1, lateral view; fig. 1*a*, occlusal view. × 3.

Fig. 2. Right maxillary with $P\underline{4}$–$M\underline{2}$, No. 2150, loc. 150. × 6.

Paramyid, gen. and sp. indet.

Fig. 3. Left lower molar, No. 2154, loc. 150. × 2.

Ischyrotomus (?) *tapensis*, n. sp.

Fig. 4. Left $P\underline{4}$, No. 2166, loc. 180. × 2.

Fig. 5. Left upper molar, No. 2165, loc. 180. × 2.

Fig. 6. Right $P\bar{4}$, No. 2159, loc. 180. × 2.

Fig. 7. Right lower molar, No. 2161, loc. 180. × 2.

Fig. 8. Left lower molar, No. 2162, loc. 180. × 2.

Figs. 9, 9*a*. Type right ramus with $P\bar{4}$–$M\bar{3}$, No. 2157, loc. 180. Fig. 9, lateral view; fig. 9*a*, occlusal view. × 2.

Paramys cf. *minutus* Wilson

Fig. 10. Right upper molar, No. 2155, loc. 180. × 4.

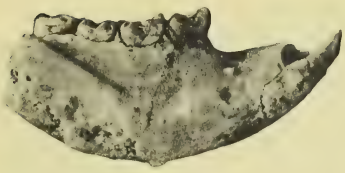
Fig. 11. Right lower molar, No. 2156, loc. 180. × 4.

Leptotomus sp.

Fig. 12. Left ramus with $P\bar{4}$–$M\bar{1}$, No. 2180, loc. 207. × 2.

Calif. Inst. Tech. Coll. Vert. Pale.
Locality 150, Sespe uppermost Eocene. Localities 180, 207, Sespe upper Eocene.

1a



1

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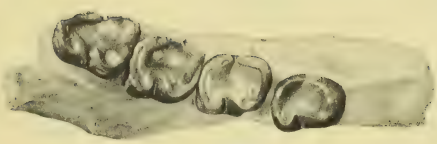
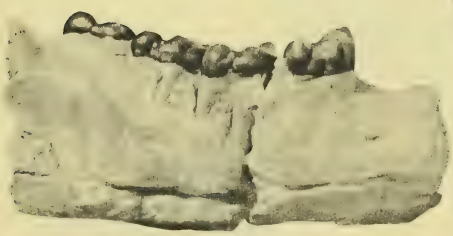
11



9a

12



9

Plate 2

Leptotomus burkei, n. sp.

Figs. 1, 1*a*. Type right ramus with $M\underline{1}$–$M\underline{3}$, No. 2172, loc. 202. Fig. 1, lateral view; fig. 1*a*, occlusal view. × 2.

Leptotomus near *burkei* Wilson

Fig. 2. Left upper molar, No. 2178, loc. 207. × 2.

Fig. 3. Right lower molar, No. 2177, loc. 207. × 2.

Rapamys fricki, n. gen. and sp.

Fig. 4. Right maxillary with $P\underline{4}$–$M\underline{3}$, No. 2183, loc. 207. × 2.

Figs. 5, 5*a*. Type left ramus with incisor and $P\underline{4}$–$M\underline{3}$, No. 2181, loc. 207. Fig. 5, lateral view; fig. 5*a*, occlusal view. × 2.

Ischyrotomus californicus, n. sp.

Fig. 6. Left upper molar, No. 2187, loc. 249. × 2.

Fig. 7. Type right ramus with $P\underline{4}$–$M\underline{3}$, No. 2185, loc. 249. × 2.

Leptotomus (?) *caryophilus*, n. sp.

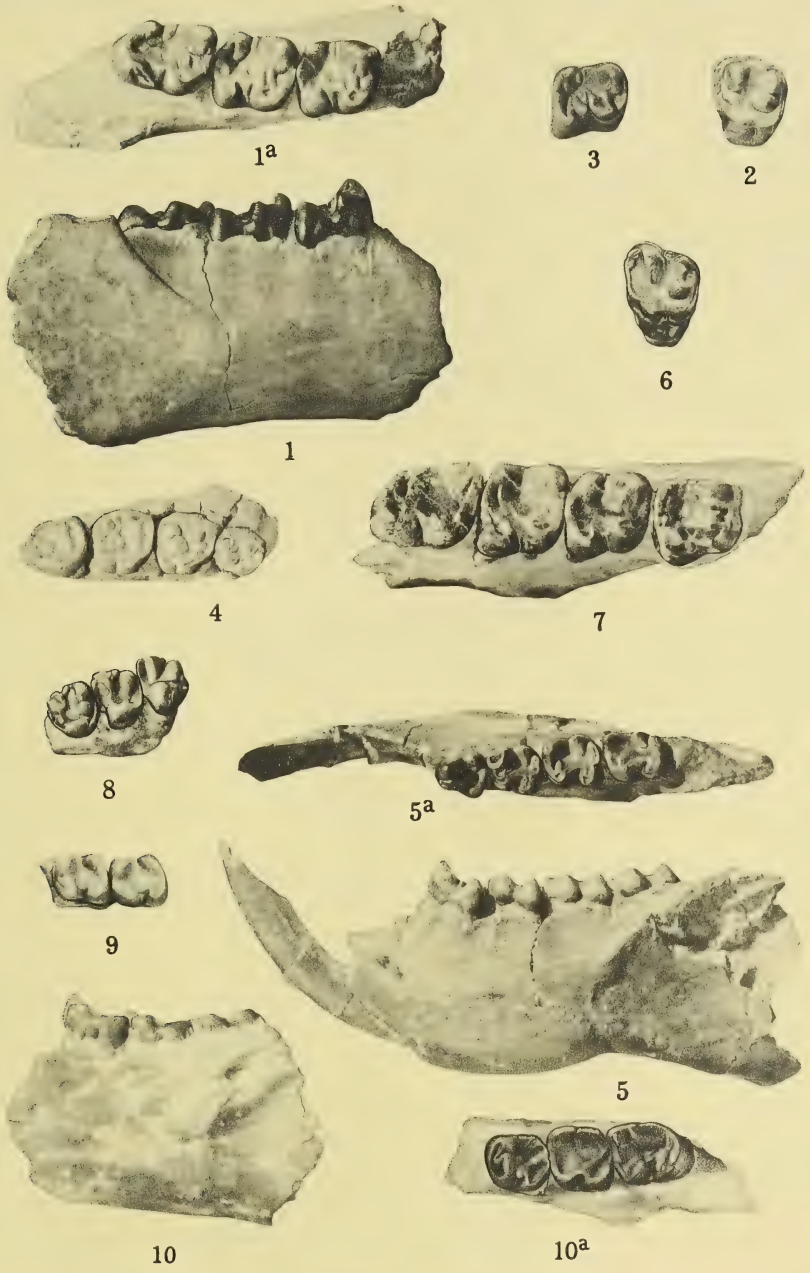
Fig. 8. Type left maxillary with $P\underline{4}$–$M\underline{2}$, No. 2189, loc. 249. × 2.

Fig. 9. Left ramus with $M\underline{1}$–$M\underline{2}$, No. 2191, loc. 249. × 2.

Paramyid (?), probably n. sp.

Figs. 10, 10*a*. Left ramus with $M\underline{1}$–$M\underline{3}$, No. 2194, loc. 249. Fig. 10, lateral view; fig. 10*a*, occlusal view. × 4.

Calif. Inst. Tech. Coll. Vert. Pale.
Localities 202, 207, Sespe upper Eocene. Locality 249, Poway upper (?) Eocene.


1a
3
2
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10a

CONTRIBUTIONS TO PALEONTOLOGY

VI

TWO NEW EOCENE RODENTS FROM CALIFORNIA

By Robert W. Wilson

With two plates

[Issued June 27, 1940]

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TWO NEW EOCENE RODENTS FROM CALIFORNIA

INTRODUCTION

One of the most common types of mammal obtained by the California Institute of Technology in quarry 249 in the Poway conglomerate, San Diego County, is a new species of the genus *Sciuravus*. The fauna of quarry 249 is apparently slightly post-Bridger, and hence the presence of this species is of especial interest since remains of *Sciuravus* younger than of Bridger age have hitherto been rare. The second form described is from the later Eocene of the Sespe formation exposed in the Brea Canyon section of the formation north of Simi Valley, Ventura County. A rodent of uncertain affinities, it is of interest because of its possible relation to the geomyoids.

Family SCIURAVIDAE Miller and Gidley

Sciuravus powayensis, n. sp.

(Plate 1; plate 2, figures 1–3)

Type specimen. Incomplete left ramus with $P\bar{4}$–$M\bar{3}$, C.I.T. No. 2281.

Paratype specimen. Fragmentary right maxillary with $P\underline{3}$–$M\underline{1}$, C.I.T. No. 2282.

Referred specimens. Several additional rami and dentitions, fragments of maxillae and dentitions, isolated cheek teeth and incisors; C.I.T. Nos. 2283 to 2304.

Locality. Poway conglomerate, west bank of the San Diego River, approximately one-quarter mile northeast of the Mission San Diego. C.I.T. Vert. Pale. Loc. 249.

Specific characters. Species averaging smaller than *Sciuravus nitidus*. Cheek teeth less hypsodont than in *S. altidens*. $P\underline{4}$ narrow anteroposteriorly, oval in outline; metaloph transverse; metaconule not distinct. Superior molars with massive, noncrescentic hypocone elongated obliquely forward without connecting crest to metacone. $P\bar{4}$ reduced in size. Inferior molar cusps, especially entoconid, relatively massive. Trigonids more nearly a unit than in typical *Sciuravus*. Ectolophid weak and cuspate. Posterior valleys of lower cheek teeth reduced. Posterolophids oblique, little curving.

Description

The skull is unknown except for several fragments of the maxillary bone. In specimen No. 2282, the anterior portion of the zygoma is preserved. The area for attachment of the masseter muscle is rather sharply defined. A ridge ending in a heavy keel marks the anterior margin of the area. The zygomatic root is well forward with its posterior edge opposite $P\underline{3}$.

Several isolated upper incisors, Nos. 2288–2289, evidently pertain to *Sciuravus powayensis*. These incisors are narrow with rounded enamel faces.

The third upper premolar is a simple cone with a posterointernal cingulum.

The fourth upper premolar is relatively small and oval in outline with the short axis anteroposterior. In paratype specimen No. 2282, the paracone is united with the inner portion of the protoloph only by a narrow

commissure, and the latter projects slightly beyond the connection with the result that the anterior edge of the loph is grooved at this point. The metacone is a large transversely oriented cusp with which the metaconule is completely fused. A hypocone is apparently present but it is not separate from the protocone, and in the present stage of wear a continuous, heavy internal crest is seen. An isolated tooth, No. 2286, also represents P4. In this specimen, the hypocone is well defined although continuous with the protocone. Also, the protoloph is complete and well developed. A slight constriction of the metaloph suggests that a metaconule was perhaps present, although this is impossible to determine in the present stage of wear. As a whole, P4 is characterized by heavy cusps and crests with crowded intervening valleys.

The first and second upper molars are nearly alike and can be described together. Perhaps the chief characters in the upper molars are better shown by M1 than by M2. The protoloph is composed of a more or less cuspate paracone, and an oblique protocone-protoconule demiloph. The degree of separation of the inner portion of the protoloph from the paracone varies apparently with stage of wear, with position of the tooth in the cheek-tooth series, and with the individual. Perhaps a less effective transverse crest is present than in *S. nitidus*. In certain individuals of *S. powayensis*, the separate character of the paracone is maintained almost to the floor of the tooth. The paracone in several instances is smaller than the metacone. The protoconule is usually discernible as a small cuspule fused to the protocone. There is no crest connecting the anterior portion of the hypocone with the metacone cusp, whereas some degree of attachment is found in most specimens of *S. nitidus*. The hypocone is a heavy obliquely compressed cusp with posterior part rounded, anterior part somewhat pointed. Essentially the whole structure agrees in character with the protoloph except that even in unworn specimens no conule is visible. Molars of *S. nitidus* have hypocones which are relatively crescentic cusps, and this difference is an important distinguishing feature of the upper dentition of the San Diego species. The mesostyle is weak in *S. powayensis*. In general, it may be said that the pattern of M1 and M2 is made up of two outer cusps and two inner, imperfect and oblique, crests. This pattern, as seen in unworn molars Nos. 2284 and 2287, approaches the basic pattern of *Simimys* and *Eumys* but at best can have only a very remote genetic relation to it.

The third upper molar is known only by No. 2285, a fragment of maxillary with M2–M3, and two isolated teeth, No. 2290. M3 of No. 2285 is equal to or perhaps slightly larger than M2. Posteriorly, the tooth is rather pointed in outline. The protoloph is complete. In the talon, the hypocone is rather slightly separated from a massive, globular, somewhat double posteromedian cusp. A low crest lies along the external border of the tooth from the latter to the base of the paracone. A rather large isolated cuspule is present in the basin. No. 2290, an M3, is smaller than that of No. 2285, with more rounded posterior margin. The former differs also in lacking the heavy posteromedian cusp, although a small, more external cuspule is present which, moreover, is connected by a crest with the cuspule of the basin. A protoconule is present in the protoloph. The second isolated M3 is too worn to make out certainly details of the pattern.

The lower jaw is similar to that of the Bridger *Sciuravus* except for slightly more anterior position of the masseteric fossa and crest. Two rather distinct mental foramina are usually present. One is somewhat anterior to

$P\bar{4}$; the other is under the posterior portion of the tooth, but size, number, and position of the foramina are variable.

The mandibular incisor is close to that of *Sciuravus nitidus* in shape and proportions.

The inferior cheek teeth increase in size from $P\bar{4}$ to $M\bar{2}$. $M\bar{3}$ is longer than $M\bar{2}$, and usually about as wide.

The fourth lower premolar is reduced distinctly in size in comparison with the first molar. In this tooth, the protoconid is nearly opposite the metaconid, giving a rather quadrate outline. The ectolophid varies from rather strongly crested to weakly cuspate. A slight ridge formed by the posterior extension of the flank of the metaconid is present, but there is no definite metastylid cuspule. Usually, the entoconid is somewhat crested, and with wear sometimes unites with the hypoconid. In one specimen, No. 2301, union is at the mid-point of the posterolophid, and in another, No. 2297, the entoconid is discrete. A narrow, and generally short, posterior valley is present.

The first two molars are similar in pattern. They have large, plump cusps and reduced valleys. The protoconid is nearly comparable to the metaconid in height; the entire trigonid is massive in appearance and more or less a unit. Metalophulid II is short and stubby, but directed obliquely backward as in other species of the genus. Metastylids are absent, or at least extremely small, but ectostylids are often present at the bases of the protoconids. Basining of the central valley is less developed than in *S. nitidus*. The ectolophid is variable. It is usually weak, cuspate, and rather internal in position. In some specimens, it is little more than a small cusp lying between the two principal outer ones. In others, it is relatively crested. Sometimes a short "mesolophid" spur is present. The entoconid is a large, robust cusp usually united to the hypoconid. In several specimens, the entoconid does not become attached to the hypoconid until after the tooth is worn. In one specimen, No. 2302, a cuspule can be seen on the hypolophid just buccal to the hypoconid. The posterolophid is short and oblique with little curvature. Characteristically, the posterior valley is reduced in comparison with that in *S. nitidus*.

The third lower molar is a large tooth exhibiting the individual variation usually seen in $M\bar{3}$ of *Sciuravus*, but possessing the robust cusps, weak ectolophid, and other characters shown by the anterior cheek teeth. The entoconid is sometimes isolated from the hypoconid-ectolophid, sometimes united. In the latter instances, the point of attachment is variable.

Comparisons and Relationships

Study of the numerous specimens of the Bridger *Sciuravus* revealed considerable variation in character.[1] Tentatively, this diversity was assumed to represent individual differences. The Poway species is represented by material almost entirely from one quarry. Hence, in this case there is reason for believing that variation is individual rather than specific. Although the specimens are not uniform in character, they are more homogeneous than those of the Bridger, and conform more readily to a species concept. Considering the relatively large stratigraphic and geographic range of the latter, this is not surprising. Reference of most of the Bridger *Sciuravus* specimens to *S. nitidus* is perhaps largely a matter of convenience, but characters of *S. powayensis* are variable enough to make it evident that care must be exercised in establishing any additional Bridger species of the

[1] R. W. Wilson, Amer. Jour. Sci., ser. 5, vol. 35, pp. 127–133, 1938.

genus. The principal characters distinguishing *S. powayensis* from average *S. nitidus* are as follows: (1) average size slightly less; (2) metaloph of $P\underline{4}$ transverse rather than directed toward protocone, without distinct metaconule rather than with; (3) hypocone of molars not crescentic, and without metacone connection; (4) $P\overline{4}$ relatively smaller; (5) molar trigonids more massive; (6) posterior valleys smaller; and (7) cusps in general more robust, valleys reduced.

The only described specimen of *Sciuravus* from the upper Eocene is the type of *S. altidens* from the Uinta B or Wagonhound member of the Uinta series.[2] This specimen, Carnegie Mus. No. 2348, is a fragment of maxillary with $P\underline{4}$–$M\underline{1}$. Compared with similar material of *S. powayensis*, the following distinctive characters are to be observed in *S. altidens:* (1) more hypsodont crowns; (2) larger size; (3) $P\underline{4}$ longer anteroposteriorly; (4) metaloph of $M\underline{1}$ more complete; and (5) mesostyles more prominent. *Sciuravus altidens* seems to be a direct descendant of the Bridger *Sciuravus.* In some ways, *S. powayensis* is intermediate between the two, but the disunion of the inner portion of the metaloph from the metacone and its marked obliquity are characters which cannot be considered as intermediate.

J. J. Burke has recently described a new species of *Sciuravus*, *S. eucristadens*, from the Green River series.[3] The type and only known specimen of this species, Carnegie Mus. No. 11871, shows several points of resemblance to the Poway form, as for example in reduced central basins, robust cusps, absence of metastylids, forward extension of the masseteric fossa, and possibly in the occasional presence of hypolophid tubercles. However, the Californian type can be distinguished by: (1) $P\overline{4}$ and $M\overline{3}$ relatively smaller in comparison with $M\overline{1}$ and $M\overline{2}$; (2) posterior valleys narrower; (3) metalophulid II not reaching floor of central valley in $M\overline{2}$; (4) metalophulid II not connecting with tubercle in floor of central valley in $M\overline{3}$; and (5) size probably smaller. Burke has suggested that *S. eucristadens* may represent a "divergent phyletic branch within the genus." Whether or not this species is referable to the *S. powayensis* line cannot be determined at present, but there are suggestive similarities in the two species. Burke found a number of points in common between *S. eucristadens* and specimens in the Carnegie Museum collections from the McCarty's Mountain Oligocene which have been referred to *Ischyromys.* The upper dentition of the Californian species certainly does not appear to be developing in the direction of an *Ischyromys* type of dentition.

Other described species of *Sciuravus* are clearly distinct from *S. powayensis.*

The exact relation of *Sciuravus powayensis* to other species of the genus is uncertain. In the upper cheek teeth, the accentuation of presumably primitive characters points to an early divergence from such forms as *S. nitidus.* The upper dentition of *S. powayensis* approaches the basic pattern of certain early Tertiary myoids. Perhaps the sciuravids are near to the stock from which these forms originated, but as evidence for this hypothesis is lacking, parallelism in dental development is a more probable explanation of similarities in structure.

Sciuravus powayensis does not furnish any convincing evidence in regard to the age of the Poway conglomerate. Data taken from the Poway mammalian fauna as a whole indicate a somewhat post-Bridger age. Characters

[2] O. A. Peterson, Ann. Carnegie Mus., vol. 12, nos. 2–4, pp. 64–65, fig. 5, 1919.

[3] J. J. Burke, Ann. Carnegie Mus., vol. 27, pp. 1–9, fig. 1, 1937.

of *S. powayensis* such as reduced $P\overline{4}$, fused metaconule in $P\underline{4}$, reduced posterior valleys in the lower molars, strong entoconid, and forward extension of masseteric crest on the ramus may also point in the same direction.

Measurements (in millimeters) of Sciuravus powayensis

	C.I.T. No. 2282	C.I.T. No. 2283
$P\underline{3}$–$M\underline{1}$, anteroposterior length (crown)	4.8	...
$P\underline{3}$–$M\underline{2}$, alveolar length	...	7.1
$P\underline{3}$, anteroposterior diameter	0.9	...
$P\underline{3}$, transverse diameter	1.0	...
$P\underline{4}$, anteroposterior diameter	1.5	...
$P\underline{4}$, greatest transverse diameter	1.9	...
$M\underline{1}$, anteroposterior diameter	2.15	...
$M\underline{1}$, greatest transverse diameter	2.3	...
$M\underline{2}$, anteroposterior diameter	...	2.1
$M\underline{2}$, greatest transverse diameter	...	2.3*

* Estimated.

	C.I.T. No. 2281	C.I.T. No. 2291	C.I.T. No. 2293	C.I.T. No. 2294
Depth of jaw at $M\overline{1}$	6.35	...	4.9	...
Depth of jaw at $M\overline{3}$	6.8	...	5.2	...
$P\overline{4}$–$M\overline{3}$, anteroposterior length	8.8	9.1	...	...
$P\overline{4}$–$M\overline{3}$, alveolar length	8.9	9.2	8.8	...
$M\overline{1}$–$M\overline{3}$, anteroposterior length	7.0	7.2−	6.8†	...
$M\overline{1}$–$M\overline{2}$, anteroposterior length	...	...	4.4	4.3
$P\overline{4}$, anteroposterior diameter	1.8	1.8	...	...
$P\overline{4}$, greatest transverse diameter	1.65	1.6+	...	...
$M\overline{1}$, anteroposterior diameter	2.2−	2.2	2.1	2.1
$M\overline{1}$, greatest transverse diameter	1.95	2.0	2.0	1.9
$M\overline{2}$, anteroposterior diameter	2.2	2.3	2.2	2.2
$M\overline{2}$, greatest transverse diameter	2.2−	2.2	2.2	2.1+
$M\overline{3}$, anteroposterior diameter	2.5	2.5	...	...
$M\overline{3}$, greatest transverse diameter	2.15	2.15	...	...

† Alveolar length.

NOTE ON THE POWAY RODENT FAUNA

The description of *Sciuravus powayensis* completes the list of known rodent species from quarry 249. The assemblage now is composed of the following types:

Ischyrotomus californicus
Leptotomus (?) caryophilus
Paramyid spp.
Paramyid (?) probably n. sp.
Pareumys near grangeri
Sciuravus powayensis

Simpson has argued that the mammalian fauna from the Bridger "probably well represents the middle Eocene life of all of America." [4] If this be true for the larger mammals, it is probably also true for the Bridger

[4] G. G. Simpson, Jour. Paleontol., vol. 10, p. 414, 1936.

rodents, which are abundant in numbers if not variety. Taxonomically, these rodents fall into three main categories which have been considered to be of family rank; namely the paramyids, sciuravids, and cylindrodonts,[5] all belonging to the primitive sciuromorph or protrogomorph division of the Rodentia. All three Bridger groups are present in the Rocky Mountains upper Eocene, although the sciuravids are apparently rare. In addition, two genera are known which are not referable to any one of these three. *Protadjidaumo*, closely related to the Oligocene *Adjidaumo*, is from a high level in the Duchesne River and may be basal Oligocene in age. *Protoptychus*, from the Uinta, is of very uncertain affinities, but is probably a protrogomorph. Rodents in the Uinta and Duchesne River are rather scarce, and apparently do not give anything like the complete picture of the fauna of the Rocky Mountains upper Eocene that the Bridger rodents do for the middle Eocene.

The Poway rodents are all protrogomorphs, and can be assigned readily to one or another of the three Bridger groups. On the whole, the Poway rodent fauna seems closely allied to that of the Bridger, but probably somewhat more advanced, although no more so than Wagonhound or Uinta B. Perhaps a tentative assignment to early Uinta B is justifiable on present evidence.

In contrast to the Poway fauna, the upper Eocene Sespe or Tapo Ranch rodents are for the most part quite widely separated from those of the Bridger, and to a lesser extent from those of the less well-known Uinta. They are divisible into five groups, of which only two occur in the Bridger, Uinta, or Poway. The sciuravids are not recorded from the Sespe, and two of the groups are non-protrogomorph and therefore supposedly higher in the rodent scale of evolution. The fauna marks a distinct advance over the Bridger in stage of evolution and diversity. Perhaps also the typically Eocene groups, as regards North America, are subordinate in it. Even with an appeal to the intercontinental migration between North America and the Old World which seems to have occurred in the later Eocene, it is necessary to place the Sespe fauna as fairly late in the Eocene. While it may be unwise to draw many conclusions from a comparison of the fragmental and localized rodent collections of the Sespe and Poway, it seems noteworthy that one is so like, and the other so unlike (for an Eocene fauna) the middle Eocene rodent fauna of the Bridger. The distinctive character of the Sespe assemblage is due probably to a combination of evolution and introduction of foreign stocks, but even if the latter were entirely responsible, it would point to an older age for the Poway. It is of course possible that the Bridger rodent fauna is not representative for the middle Eocene of all of North America, but the resemblance of the Poway fauna to the latter indicates otherwise.

[5] Earlier publications of Burke and Wilson refer to the Eocene representatives as ischyromyids.

Incertae Sedis, or GEOMYOIDEA (?)

GRIPHOMYS, n. gen.

Genotype. *Griphomys alecer*, n. sp., this publication.

Diagnosis. Dentition $\frac{1}{1}, \frac{0}{0}, \frac{1}{1}, \frac{3}{3}$; brachydont. Cheek teeth becoming bilophate; upper and lower molars essentially mirror images. Upper cheek teeth quadritubercular in structure with anterior and posterior cingula. Lower cheek teeth quadritubercular, with mesoconid vestigial (?) or absent. Lower molars with anterior cingula. Protoconid and metaconid of $P\bar{4}$ closely appressed. Masseteric muscle scar extending to beneath $P\bar{4}$. Zygomatic plate tilted upward.

Specimens of this new genus are known from three levels in the Sespe formation, as recorded below.

Griphomys alecer, n. sp.

(Plate 2, figure 6)

Type. Fragmentary right ramus with $P\bar{4}$–$M\bar{2}$, C.I.T. No. 2522.

Locality. Tapo Ranch fauna. C.I.T. Vert. Pale. Loc. 207.

Specific characters. Vestigial mesoconids (?) discernible. $P\bar{4}$ subtriangular, basin not especially reduced. Width of trigonids of molars equal to or less than that of talonids.

Griphomys near alecer, n. sp.

(Plate 2, figure 7)

Material. Fragmentary right ramus with $M\bar{1}$–$M\bar{2}$, C.I.T. No. 2523.

Locality. Tapo Ranch fauna. C.I.T. Vert. Pale. Loc. 202.

Remarks. This specimen, from a level 75 feet higher than that of No. 2522, is very close to the type, and may be specifically identical with it. However, No. 2523 differs in having slightly wider trigonids, and in exhibiting, in the presence of a small spur from the hypoconid of $M\bar{1}$, a slightly less continuous posterior loph.

Griphomys near alecer, n. sp.

(Plate 2, figures 4, 5, 8, 8*a*)

Material. Incomplete left ramus with $P\bar{4}$ and $M\bar{2}$, C.I.T. No. 2524; fragment of left maxillary with $P\underline{4}$–$M\underline{1}$, C.I.T. No. 2525; and a right upper molar, C.I.T. No. 2526.

Locality. Pearson Ranch fauna. C.I.T. Vert. Pale. Loc. 150.

Remarks. Considering the individual variation found in many rodents of comparable age, the locality 150 specimens might be referred to *Griphomys alecer*. On the other hand, the stratigraphic interval, 675 feet, separating the two localities is considerable. This and the differences cited below suggest the possibility of specific separation with better material.

$P\bar{4}$ of No. 2524 differs from that of the type in its slightly smaller size and less triangular shape, and is slightly less basined. In $M\bar{2}$ the minute vestige of the mesoconid (?) present in the specimens from localities 207 and 202 is absent. The tooth row is shorter than in either No. 2522 or No. 2523.

Description of Griphomys

The following description is based on all known material, and a considerable stratigraphic range is covered by the specimens. Upper cheek teeth have been recovered so far only from the highest occurrence, locality 150. However, lower jaw material from all localities is very similar, and the upper cheek teeth agree so closely in pattern with the lowers that little doubt can be felt concerning their association.

Specimen No. 2525 has a portion of the zygomatic root preserved. This fragment exhibits a tilted zygomatic plate similar to that possessed by most modern rodents and unlike the corresponding structure in the primitive protrogomorph members of the order. In view of its fragmentary nature, possibly the plate is an extreme example of the type possessed by the protrogomorph rodent *Ischyromys*, but there is no evidence to support this conclusion. The dentition in No. 2525 is well worn, but enough of the pattern of $P\underline{4}$ remains to demonstrate the bilophate, quadritubercular character of the tooth. Apparently $P\underline{3}$ is not present in *Griphomys*.

A less worn upper cheek tooth is represented by upper molar No. 2526. In general pattern it is quite similar to the lower molars to be described. The tooth is bilophate, and quadrate in outline. The anterior loph is somewhat concave posteriorly. Two cusps can be distinguished with some evidence of a third, median one. A low anterior cingulum is present. The posterior loph is bifurcate externally, the posterior branch being the cingulum. Individual cusps cannot be seen in the present stage of wear.

The lower jaw is not well preserved in any of the specimens. Apparently it is relatively heavy, and deep anteriorly. The superior border of the ramus between $P\overline{4}$ and $\overline{I}$ is concave instead of nearly straight as in the Eocene protrogomorph type of rodent. A prominent mental foramen lies rather high on the ramus. The masseter lateralis ridge is sharp and well defined, curving upward slightly at its anterior end. It extends to beneath $P\overline{4}$. A less distinct masseter medialis ridge is present.

The mandibular incisor is slightly flattened at the anterior surface.

In the cheek teeth preserved, $P\overline{4}$–$M\overline{2}$, the premolar is the smallest tooth. $M\overline{1}$ and $M\overline{2}$ are subequal although perhaps the latter is larger. $P\overline{4}$ is rather triangular in the type specimen from locality 207. The corresponding tooth in No. 2524, locality 150, is more ovate. $M\overline{1}$ is slightly longer than wide; $M\overline{2}$ is nearly equidimensional.

The premolar has a massive trigonid, median basin, and heavy, curving posterior crest. The protoconid and metaconid are fused except at the apex of the trigonid. In No. 2522, the two cusps are joined in the rear, only very slightly apart in front, but are separated medianly by a pit. No. 2524 differs in that the protoconid and metaconid are united medianly although a slight groove is still present anteriorly. The mesoconid is absent, but an ectostylid is present in No. 2522. The median basin is reduced in the locality 150 specimen in comparison with that in the type. Hypoconid and entoconid cusps are represented in the posterior crest principally as swellings in the enamel, but the crest between them is depressed.

$M\overline{1}$ and $M\overline{2}$ have essentially the same pattern. It is composed of an anterior cingulum, and two slightly bowed crests each concave anteriorly with more of a valley than a basin between them. Each crest is bicuspate. A minute cuspule in the central valley or basin of both $M\overline{1}$ and $M\overline{2}$ may represent the last vestige of the mesoconid. This structure is present in specimens from localities 207 and 202 but is absent in that from locality 150. The two molars in the 202 specimen apparently have slightly wider tri-

gonids than those of 207. In addition, the posterior crest of $M\bar{1}$ in the former exhibits an entoconid which is slightly separated from the outer portion of the crest.

Relationships of Griphomys

The affinities of *Griphomys* are very uncertain. No form with which the writer is familiar is close to the Sespe genus. Reference to the Geomyoidea is little more than a guess, but *Griphomys* is closer to this group in its major features [6] than to any other North American division of the Rodentia. Possibly the genus represents a family previously unrecognized, but the present material is too scanty to establish this. Among geomyoids, the pattern of *Griphomys* is closest in some respects to that of *Florentiamys*,[7] but the differences are great. This latter genus is of dubious affinities. The lower cheek teeth of *Griphomys* approach the paramyid type, but the upper dentition is quite far removed.

Measurements (in millimeters) of Griphomys

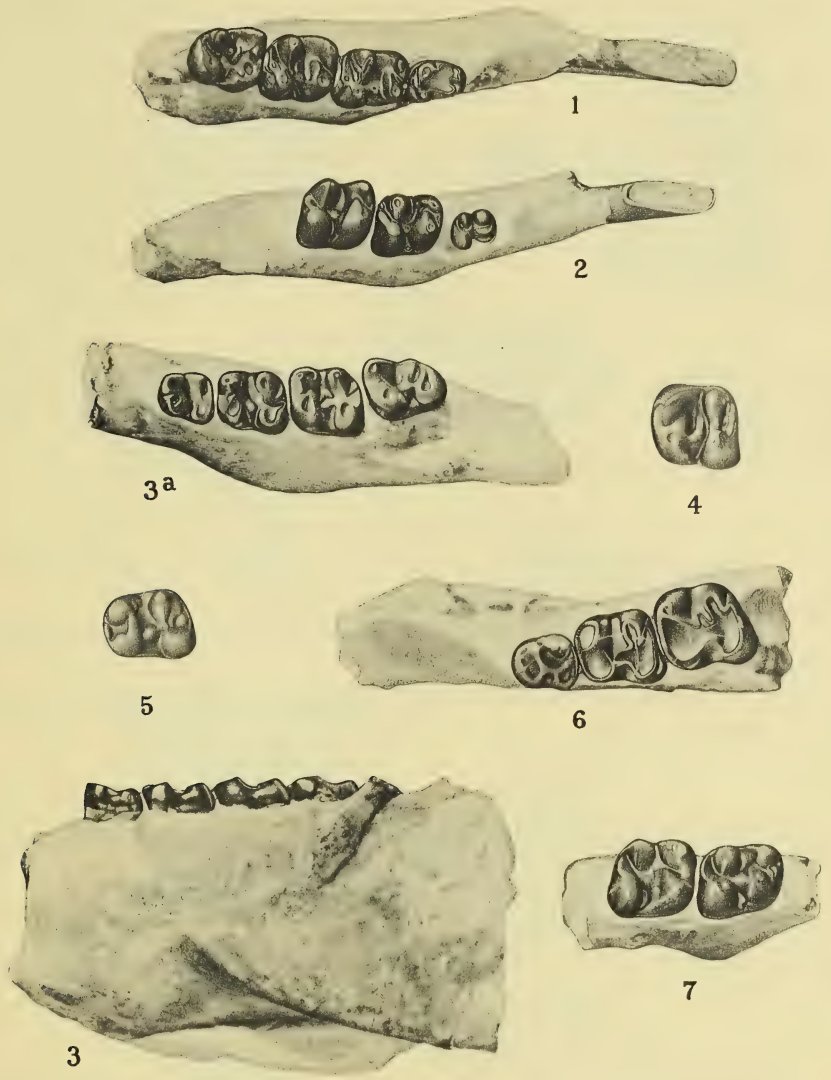
	G. alecer C.I.T. No. 2522 Loc. 207 Type	*G.* near *alecer* C.I.T. No. 2523 Loc. 202	*G.* near *alecer* C.I.T. No. 2524 Loc. 150
$P\bar{4}$–$M\bar{2}$, anteroposterior length	3.9	3.9*	3.45
$M\bar{1}$–$M\bar{2}$, anteroposterior length	2.65	2.65	....
$P\bar{4}$–$\bar{I}$, length of diastema	2.5	....	2.5
$\bar{I}$, anteroposterior diameter	...	....	1.45
$\bar{I}$, transverse diameter	...	....	0.85
$P\bar{4}$, anteroposterior diameter	1.2	....	1.1+
$P\bar{4}$, greatest transverse diameter	1.1	....	1.0
$M\bar{1}$, anteroposterior diameter	1.3	1.3	....
$M\bar{1}$, greatest transverse diameter	1.2	1.25	....
$M\bar{2}$, anteroposterior diameter	1.3	1.4	1.35
$M\bar{2}$, greatest transverse diameter	1.3	1.4	1.2

	G. near *alecer* C.I.T. No. 2525 Loc. 150	*G.* near *alecer* C.I.T. No. 2526 Loc. 150
$P\underline{4}$–$M\underline{1}$, anteroposterior length	2.55*	....
$P\underline{4}$, anteroposterior diameter	1.2	....
$P\underline{4}$, greatest transverse diameter	1.3	....
$M\underline{1}$, anteroposterior diameter	1.2	....
$M\underline{1}$, greatest transverse diameter	1.45 (?)	....
$\underline{M}$, anteroposterior diameter	....	1.35
$\underline{M}$, greatest transverse diameter	....	1.4

* Alveolar measurement.

[6] For example: (1) tilted zygomatic plate, masseter muscle scar extending to beneath $P\bar{4}$; (2) dental formula apparently 1/1, 0/0, 1/1, 3/3; (3) upper cheek teeth fundamentally quadritubercular; (4) cheek teeth becoming bilophate; and (5) mesoconid absent or vestigial (?).

[7] A. E. Wood, Amer. Jour. Sci., ser. 5, vol. 31, pp. 41–49, figs. 1–8, 1936.



Sciuravus powayensis, n. sp.

Fig. 1. Right ramus with $P\overline{4}$ (?), $M\overline{1}$–$M\overline{3}$, No. 2292. × 4.

Fig. 2. Right ramus with unerupted $P\overline{4}$, $M\overline{1}$–$M\overline{2}$, No. 2293. × 4.

Figs. 3, 3*a*. Left ramus with $P\overline{4}$–$M\overline{3}$, type specimen No. 2281. Fig. 3, lateral view; fig. 3*a*, occlusal view. × 4.

Fig. 4. Left lower molar, No. 2303. × 5⅓.

Fig. 5. Left lower molar, No. 2302. × 5⅓.

Fig. 6. Fragmentary left ramus with $P\overline{4}$–$M\overline{2}$, No. 2297. × 5⅓.

Fig. 7. Fragmentary right ramus with $M\overline{1}$–$M\overline{2}$, No. 2294. × 5⅓.

Sizes of all figures approximate.
Calif. Inst. Tech. Coll. Vert. Pale.
Locality 249, Poway upper (?) Eocene.

Plate 2

Sciuravus powayensis, n. sp.

Fig. 1. Fragment of left maxillary with M1 (?), No. 2284, loc. 249. × 5⅓.

Fig. 2. Fragmentary right maxillary with P3–M1, paratype specimen No. 2282, loc. 249. × 5⅓.

Fig. 3. Fragment of left maxillary with M2–M3, No. 2285, loc. 249 × 5⅓.

Griphomys near *alecer*, n. gen. and sp.

Fig. 4. Fragmentary left maxillary with P4–M1, No. 2525, loc. 150. × 6⅔.

Fig. 5. Right upper molar, No. 2526, loc. 150. × 6⅔.

Fig. 7. Fragmentary right ramus with M2 (M1 destroyed since text description), No. 2523, loc. 202. × 6⅔.

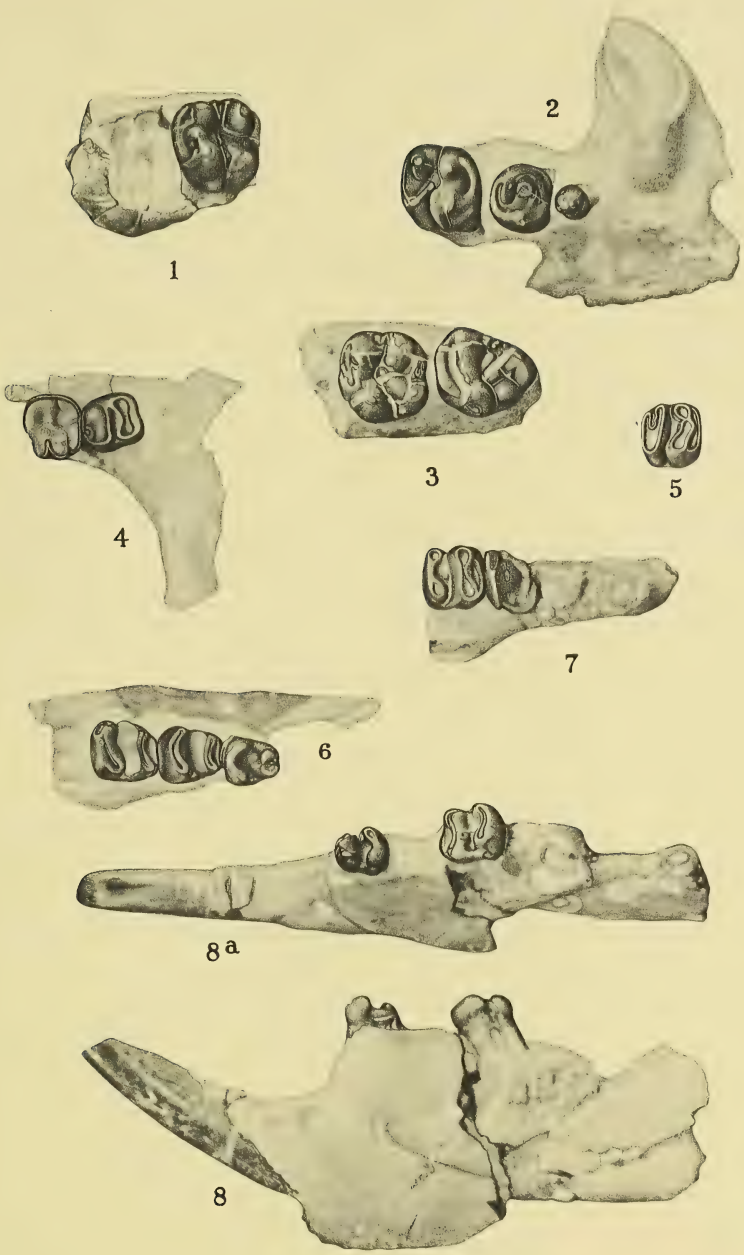
Fig. 8, 8*a*. Left ramus with P4 and M2, No. 2524, loc. 150. Fig. 8, lateral view; fig. 8*a*, occlusal view. × 6⅔.

Griphomys alecer, n. gen. and sp.

Fig. 6. Fragmentary right ramus with P4–M2, type specimen No. 2522, loc. 207. × 6⅔. Sizes of all figures approximate.

Calif. Inst. Tech. Coll. Vert. Pale.

Locality 249, Poway upper (?) Eocene. Locality 150, Sespe uppermost Eocene. Localities 202, 207, Sespe upper Eocene.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CONTRIBUTIONS TO PALEONTOLOGY

VII

PAREUMYS REMAINS FROM THE LATER EOCENE OF CALIFORNIA

By Robert W. Wilson

With two plates

[Issued June 27, 1940]

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PAREUMYS REMAINS FROM THE LATER EOCENE OF CALIFORNIA

INTRODUCTION

Specimens referable to the genus *Pareumys* are now known from three localities in the Sespe formation and one locality in the Poway conglomerate.[1] Unfortunately, the material is extremely fragmentary although not especially rare. On the other hand, a number of isolated upper cheek teeth have been obtained, and the upper dentition has been recorded previously only by a single upper molar of *Pareumys* (?) *troxelli*. In addition, the stratigraphic range of the Californian specimens is relatively great, and increases somewhat our knowledge concerning the evolution and affinities of the genus.

Family CYLINDRODONTIDAE Miller and Gidley

Genus **PAREUMYS** Peterson

Pareumys may be defined at present as follows:

Dentition. $\frac{1}{1}, \frac{0}{0}, \frac{2\,(?)}{1}, \frac{3}{3}$; cheek teeth brachydont to subhypsodont. Incisors of moderate width, semi-flattened. Superior cheek teeth with small hypocones but cingular and not discrete from protocones. Protoloph with protoconule indistinct or more often completely fused into crest. Metaloph incomplete, distinctly separated from inner wall of tooth; primitively transverse in orientation, progressively oblique and strongly attached to median part of posteroloph. Inferior cheek teeth basically as in *Mysops* but with stronger crests, and trigonid and talonid of more nearly equal elevation; progressively trending toward flat-topped cheek teeth. Posterior valleys generally open. Ramus progressively deep anteriorly. Skull undescribed and skeleton unknown.

Uppermost Eocene: Locality 150, Pearson Ranch Fauna, Sespe Formation

Pareumys near **milleri** Peterson

(Plate 1, figures 1, 2, 6; plate 2, figures 1, 1*a*)

Fragmentary remains of the genus *Pareumys* from locality 150 indicate the presence of a species near *P. milleri*.[2] This material consists of a left ramus with incisor and well-worn $P\bar{4}$–$M\bar{3}$, C.I.T. No. 2209; a fragment of left ramus with $M\bar{1}$–$M\bar{2}$, C.I.T. No. 2210; and several isolated cheek teeth, C.I.T. Nos. 2211, 2213–2215. The locality 150 specimens exhibit some variation in characters but they are too incomplete to demonstrate that

[1] For location and stratigraphic information concerning these localities see R. W. Wilson, Carnegie Inst. Wash. Pub. No. 514, paper V, pp. 59–83.

[2] O. A. Peterson, Ann. Carnegie Mus., vol. 12, nos. 2–4, p. 66, fig. 7, 1919. J. J. Burke, Ann. Carnegie Mus., vol. 25, p. 8, fig. 3, 1935.

the variation is more than individual, especially since the material was obtained from one quarry.

The Sespe specimens agree rather closely in characters with the two known specimens of *Pareumys milleri*, Carnegie Mus. Nos. 2938 and 12062, but differ from the Uinta material in the following: (1) $P\overline{4}$ slightly more reduced, hypolophid apparently incomplete, not uniting with ectolophid as in the Uinta species; (2) $M\overline{1}$ and $M\overline{2}$ narrower transversely; (3) crowns of cheek teeth apparently slightly flatter-topped, i.e. all cusps and crests more nearly on a level; and (4) masseter muscle scar perhaps less anterior in position. Individually they show other differences which, however, vary from specimen to specimen. Judging from a study of *Mysops*[3] and the *Mysops-Pareumys* group in general, all four of the above characters could be or are subject to individual variation. (3) is probably the most important, and, as the stratigraphic position of locality 150 suggests, points to a species slightly advanced over that from the Myton (Uinta C). However, the difference is slight, and the advanced characters of the Sespe species may be real but due to chance in collecting of individual variants, or perhaps even caused by wear and mostly illusionary.

The Pearson Ranch species is clearly advanced over *Pareumys grangeri* of the Wagonhound (Uinta B).[4] This is seen especially in the flatter-topped cheek teeth. The chief contributing factors in this regard are the higher ectolophids and stronger hypolophids. In addition, the Californian species is larger, $P\overline{4}$ is more reduced, and protoconids appear to be more crescentic. *Pareumys* (?) *troxelli*[5] from the Wagonhound is also distinct from and less advanced than the Sespe form. The latter is higher-crowned; cusps more erect; hypolophid stronger, in less continuous curve with ectolophid; posterolophid shorter; and posterior valleys, at least in $M\overline{2}$, broader. The upper teeth also show noteworthy differences as indicated below.

Two isolated upper cheek teeth of *Pareumys* near *milleri* from the Pearson Ranch fauna are of particular interest since they pertain to a species close to the type species, and since the upper dentition of the genus has been known previously only by a single upper molar of *P.* (?) *troxelli*. These teeth probably represent $M\underline{1}$ and $M\underline{2}$. The latter, No. 2214, has well-developed cingula, a complete protoloph, and an incomplete metaloph. In the present stage of wear, all crests are about at the same level, and the tooth is nearly flat-topped. No. 2214 is slightly narrowed posteriorly. The hypocone is weakly developed. It is continuous with the protocone and apparently is produced by the elevation and slight swelling of the posterior cingulum or posteroloph. The anterior cingulum or anteroloph is moderately developed. Originally the anterior cingulum was lower than the protoloph, but in the present stage of wear, it is nearly equal to the protoloph in elevation. The protoloph is transverse and without visible protoconule. The metaloph is incomplete, being entirely free from the wall of the protocone-hypocone. It is directed posterointernally and is strongly united to about the mid-point of the posteroloph. Because of this, a small basin is present between the metaloph and posteroloph. The floor of the central basin is deepest between hypocone and metaloph. The walls of the basin are steep except where the basin issues externally between paracone and metacone. $M\underline{1}$ (?), No. 2215, is larger, less elongate, and not narrowed

[3] R. W. Wilson, Amer. Jour. Sci., ser. 5, vol. 35, pp. 214–217, 1938.
[4] J. J. Burke, *op. cit.*, pp. 7–9, fig. 2, 1935.
[5] *Ibid.*, pp. 9–12, fig. 4, 1935.

posteriorly. The hypocone appears to be better developed than in No. 2214. Otherwise the two specimens are comparable except that No. 2215 is more heavily worn, a circumstance which has caused the posterior basin to be preserved only as an enamel islet. Compared with the upper tooth of *P.* (?) *troxelli* figured by Burke, the Sespe specimens are distinguished by: (1) more hypsodont crown; (2) anterior cingulum perhaps shorter but higher, forming more of the actual pattern of the occlusal surface; and (3) metaconule joined to posteroloph—free in *P.* (?) *troxelli*.

Measurements (in millimeters) of Pareumys near milleri

	C.I.T. No. 2209	C.I.T. No. 2210
$\underline{I}$, anteroposterior diameter	2.5	...
$\underline{I}$, transverse diameter	1.9	...
Length of diastema, $\underline{I}$–$\underline{P4}$	4.5	...
Depth of ramus beneath $\underline{M1}$	7.3	...
$\underline{P4}$–$\underline{M3}$, anteroposterior length	7.35	...
$\underline{P4}$–$\underline{M3}$, alveolar length	7.9	...
$\underline{M1}$–$\underline{M2}$, anteroposterior length	3.8	4.2
$\underline{P4}$, anteroposterior diameter	1.6	...
$\underline{P4}$, greatest transverse diameter	1.6	...
$\underline{M1}$, anteroposterior diameter	1.7	2.0
$\underline{M1}$, greatest transverse diameter	1.9	1.8
$\underline{M2}$, anteroposterior diameter	2.0	2.2
$\underline{M2}$, greatest transverse diameter	2.2	2.05
$\underline{M3}$, anteroposterior diameter	2.15	...
$\underline{M3}$, greatest transverse diameter	1.95	...
	C.I.T. No. 2215	C.I.T. No. 2214
$\underline{M1}$ (?), anteroposterior diameter	2.1	...
$\underline{M1}$ (?), transverse diameter	2.4	...
$\underline{M2}$ (?), anteroposterior diameter	...	1.9
$\underline{M2}$ (?), transverse diameter	...	1.95

Upper Eocene: Locality 202, Tapo Ranch Fauna, Sespe Formation

Pareumys sp.

(Plate 1, figure 7; plate 2, figures 2, 2*a*)

Several very fragmentary specimens represent the genus *Pareumys* at locality 202. The material comprises the following: right ramus with incisor and worn $\underline{M2}$, No. 2217; fragment of left ramus with $\underline{M3}$, No. 2216; and two isolated third lower molars, Nos. 2218, 2219. No specific identification can be made on the basis of existing remains, but the species represented is probably more advanced than *P. grangeri*. The Sespe species may be distinct from *P. milleri*, but this cannot be determined with the present fragments. Lack of comparable elements or different stages of wear in the cheek teeth makes comparisons with *Pareumys* near *milleri* from locality 150 of no value. The stratigraphic interval separating 150 and 202 and a comparison of the mammalian species from the two localities, however, strongly suggests distinct species. *P.* (?) *troxelli* is apparently distinct specifically from the species under discussion.

The Sespe species is essentially comparable to *Pareumys milleri* in size. It differs in having the posterolophid of $\underline{M3}$ slightly longer and more curved, and perhaps in better development of metastylid ridges.

The type specimen of *Pareumys grangeri* is distinguished from locality 202 specimens by smaller size, and less flat-topped M3.

No. 2217 is the only locality 202 individual with which the type of *Pareumys* (?) *troxelli* can be compared directly. Unfortunately, M2 of the former is worn to a point where comparisons with *P.* (?) *troxelli* are difficult to make. The Sespe specimen is larger; M2 is relatively broad in front, whereas the trigonid of *P.* (?) *troxelli* is relatively narrow, and the tooth lacks the continuous curve of the ectolophid-hypolophid crests seen in cheek teeth of the Uinta species.

Pareumys (?) sp.

(Plate 1, figures 8, 8*a*)

Included in the specimens from locality 202 is a fragment of left ramus with M2, No. 2221, which differs from the material assigned to *Pareumys* sp., and also from other representatives of Sespe *Pareumys*. M2 of this specimen is distinctive in having the posterior valley completely enclosed as a deep basin by the extension of the posterolophid to unite with the entoconid almost at the apex of the cusp. In addition, No. 2221 seems to be somewhat smaller than other Sespe specimens of *Pareumys*, and higher-crowned as well where height of crown can be determined. The posterior wall of the trigonid is relatively steep.

Pareumys (?) sp. seems clearly distinct from Uinta species of *Pareumys*. In general, the Uinta species have lower, less flat-topped crowns, and none shows the large, deep, and completely enclosed posterior basin.

The lower dentitions of the Oligocene rodents *Pseudocylindrodon* and *Cylindrodon* have patterns similar to that of *Pareumys*. Cheek teeth of *Pseudocylindrodon neglectus* possess posterior basins dammed by the fusion of posterolophid to entoconid. Wood has figured [6] a rodent specimen determined as *Cylindrodon* aff. *fontis* which exhibits a closed posterior valley. However, No. 2221 is much closer to *Pareumys* in general structure than to these species. No. 2221 might possibly represent a variant of one of the Sespe species of *Pareumys*, but the apparently more hypsodont teeth suggest otherwise.

Upper Eocene: Locality 207, Tapo Ranch Fauna, Sespe Formation

Pareumys sp.

(Plate 1, figures 3, 10)

A slightly worn left upper cheek tooth, No. 2224, from locality 207 is referable to the genus *Pareumys*. This tooth is of uncertain position in the maxillary. It is rather rectangular in outline, but is widest across the protoloph, and may represent possibly an M2. The anterior pressure facet is large but the posterior facet, if present, is extremely ill defined. However, the tooth does not have the appearance of a third molar.

Doubt as to position in the maxillary of No. 2224 and the two upper cheek teeth from locality 150 makes comparisons uncertain. Locality 150 teeth may be somewhat larger. No. 2224 has a more distinct groove on the inner wall of the tooth separating protocone and hypocone lingually, and the cusps in general are more discrete. Disparity in wear and individual variation may account for the difference. On the whole the pattern is

[6] A. E. Wood, Trans. Amer. Philos. Soc., n. s., vol. 28, pt. 2, pp. 202–203, fig. 28, 1937.

rather close. All three upper teeth agree in having the metaconule united to the posteroloph, and in clear separation of that cuspule from the inner half of the tooth.

Assuming that both No. 2224 and the upper cheek tooth of *Pareumys* (?) *troxelli* figured by Burke represent the second molar, the following differences are evident in the Sespe specimen: (1) tooth more quadrate in outline; (2) metaconule joined to posteroloph—free in *P.* (?) *troxelli*; (3) protoloph perhaps slightly more crested; (4) paracone apparently relatively compressed transversely, hence more marginal; (5) more hypsodont crown; and (6) hypocone area slightly more elevated, but hypocone no more differentiated. So far as the present evidence is concerned, the Sespe species is more advanced.

In addition to the upper molar, a fragment of right ramus with deeply worn M$\bar{1}$–M$\bar{3}$, No. 2222, and a poorly preserved left ramus with $\bar{1}$ and deeply worn M$\bar{1}$–M$\bar{3}$, No. 2223, are also present. Upper molar No. 2224 represents an animal which seems distinctly smaller than those represented by the rami. However, position in the maxillary, individual variation in size, and changes in proportion and size of occlusal surface with wear are factors which may influence size of individual teeth. Discrepancy in size does not appear to be any greater than in some other rodent species in related groups; for example, see measurements of *Ardynomys occidentalis* as given by Burke.[7] As a matter of fact, this same difference in size, although perhaps less pronounced, is to be noted for specimens from locality 150 if the position assigned to the isolated upper teeth is correct. The two rami from locality 207 are comparable in size but proportions of M$\bar{1}$ are different and cheek-tooth pattern also varies in detail. Posterolophids may be more transverse, and longer than in *P. milleri*—perhaps more as in *P. grangeri*.

Comparison of Nos. 2222 and 2223 with other Sespe and with Uinta specimens is hardly practicable. The incisor of No. 2223 is notably lighter than in comparable material from localities 202 and 150. In addition, there are some other dental differences, and the 207 species may well be distinct from those at higher levels in the Sespe. There is no valid evidence that *Pareumys* sp. is conspecific with any of the Uinta species.

While more than one species may be represented by the known material of *Pareumys* from locality 207, this is doubtful. In any case, the existing specimens are certainly inadequate for specific separation.

Upper (?) Eocene: Locality 249, Poway Conglomerate

Pareumys near **grangeri** Burke

(Plate 1, figures 4, 5, 9; plate 2, figures 3, 3*a*)

A species close to *Pareumys grangeri* is represented at locality 249 by a lower right dentition with M$\bar{1}$–M$\bar{3}$, C.I.T. No. 2225; a left ramus with M$\bar{1}$–M$\bar{3}$, C.I.T. No. 2226; a fragment of right ramus with M$\bar{1}$–M$\bar{2}$, C.I.T. No. 2227; and several upper cheek teeth, C.I.T. Nos. 2228–2231. The Poway species is evidently more primitive than *P. milleri* and *Pareumys* species from the Sespe. Characters listed by Burke as distinguishing *P. grangeri* from *P. milleri* hold in general also for the Californian material except that in the latter the ramus is deep, the posterior valleys of the cheek teeth are not always demonstrably narrower than in *P. milleri*, and the

[7] J. J. Burke, Ann. Carnegie Mus., vol. 25, pp. 148–149, 1936.

ectolophid in M$\bar{3}$ of No. 2225 is rather angulate. Additional characters separating *P. grangeri* from locality 249 specimens may be: (in *P.* near *grangeri*) (1) an apparently shorter diastema and (2) protoconids perhaps more rounded. The two species are about comparable in size. If there is a difference in stage of development, the Californian specimens are slightly more primitive.

Pareumys (?) *troxelli* is distinct from the present species, as the following comparisons indicate: (In *P.* near *grangeri*) (1) ectolophid not forming a continuously curving crest with hypolophid; (2) posterolophid more robust, less attenuate; (3) external valleys of lower molar not especially narrowed or directed posterointernally; (4) metalophulid II not directed obliquely or descending low on flank of metaconid; (5) anterior valleys or basins of lower molars probably less broad anteroposteriorly, and not so deep; (6) protoconule less distinct; and (7) anterior cingulum of upper molars of lesser development, anterointernal groove marking protocone–anterior cingulum boundary slight. *P.* (?) *troxelli* appears to be a somewhat larger species.

The lower jaw material of Poway *Pareumys* represents a species distinctly less advanced than *Pareumys* from Sespe locality 150, and also localities 207 and 202, although the evidence here is not so strong because of the fragmentary material obtained at these places. Comparison of the upper dentition of *P.* near *grangeri* with the single upper molar recorded from locality 207 yields noteworthy differences several of which indicate that the Poway species is more primitive. The Poway cheek teeth are about comparable in size to No. 2224, Sespe locality 207, but perhaps represent a smaller species (the lower cheek teeth are distinctly smaller than lower molars from locality 207). The principal distinction is in the metaloph, which is essentially transverse with metaconule free, or nearly so, from the posteroloph—not rotated posteriorly as in the Sespe species. Paracone and metacone are less marginal and less transversely compressed. The median basin is of more even depth, hence the external opening is more pronounced. A mesostyle is present although it may be small, whereas this element is apparently absent in No. 2224. The lingual groove separating protocone and hypocone is less defined but the hypocone is essentially as prominent. The posteroloph is distinctly curved and the cheek teeth in general have less rectangular outlines. The protoloph is perhaps slightly less crested, and the anterior valley generally shallower. The Poway teeth may be less flat-topped and hypsodont, but paucity of material, stage of wear, and uncertain position of individual teeth in the maxillary combine to make this doubtful. The upper cheek teeth from locality 150 seem even more advanced over the Poway specimens in weakening of individual cusps and strengthening of the crests, but cheek-tooth wear makes this somewhat difficult to establish certainly.

Pareumys near *grangeri* is a primitive species of the genus. An alternative would be to view it as an advanced *Mysops*, since some of its characters probably are duplicated essentially in *Mysops*. However, the Poway specimens do not exhibit any of the primitive or otherwise non-*Pareumys* features seen in a number of *Mysops* specimens, and conversely in characters such as size (somewhat larger than in *Mysops*), and complete detachment of metaconule from protocone together with transverse alignment of loph,[8] they seem advanced over any specimens of *Mysops*.

[8] Except in M$\underline{3}$, in which metaloph unites with protocone; but this tooth is otherwise unknown in *Pareumys*.

Measurements (in millimeters) of Pareumys near grangeri

	C.I.T. No. 2226	C.I.T. No. 2225	C.I.T. No. 2227
Length of diastema, $\bar{I}$–$P\bar{4}$	2.8*	...	...
Depth of ramus beneath $M\bar{2}$	6.0	...	...
$P\bar{4}$–$M\bar{3}$, alveolar length	8.1	...	...
$M\bar{1}$–$M\bar{3}$, anteroposterior length	5.95	5.6	...
$M\bar{1}$, anteroposterior diameter	1.7	1.7	1.7
$M\bar{1}$, greatest transverse diameter	1.7–	1.7	1.7–
$M\bar{2}$, anteroposterior diameter	1.8	1.8	1.9
$M\bar{2}$, greatest transverse diameter	1.8	1.8	1.9
$M\bar{3}$, anteroposterior diameter	2.4	2.1	...
$M\bar{3}$, greatest transverse diameter	1.95	1.7	...

	C.I.T. No. 2230	C.I.T. No. 2231	C.I.T. No. 2229	C.I.T. No. 2228
$\underline{M}$, anteroposterior diameter	1.6	1.8	1.6	...
$\underline{M}$, greatest transverse diameter†	2.0	2.1	1.9	...
$M\bar{3}$, anteroposterior diameter	...	...	...	1.9
$M\bar{3}$, greatest transverse diameter	...	...	...	2.0 (?)

* Estimated.
† Transverse measurements are almost impossible to determine accurately in isolated cheek teeth.

RELATIONSHIPS OF PAREUMYS

Pareumys was assigned originally to the Muridae by Peterson and comparisons made with *Eumys*.[9] In 1935, the present author suggested that the genus was not murine, and that it was "quite possibly an ancestor to *Cylindrodon*." [10] Later in the same year, Burke, describing new material of *Pareumys*, referred the genus to the Ischyromyidae.[11] He thought that *P. milleri* and *P. grangeri* were evolving in the direction of an "Ischyromys-like dentition," but that *P.* (?) *troxelli* had "the structural possibilities of evolution toward *Cylindrodon*." However, Burke felt that "the ancestor of *Cylindrodon* in the Upper Eocene had progressed beyond the stage represented by *Pareumys* (?) *troxelli*." In 1937, A. E. Wood repeated the assignment of *Pareumys* to the Ischyromyidae and stated:

> The pre-Oligocene history of the ischyromyids can be sketched only in the most general terms. The most logical assumption at present is that they were derived from the stock of rodents represented by the Bridger sciuravids, as was indicated by Burke. The Uinta genus *Pareumys* apparently represents a stage intermediate between *Ischyromys* and the forms Troxell included under the genus *Tillomys*. Its exact relationships with either genus, however, are not quite clear at the present time.[12]

It should be mentioned in connection with the above that the Ischyromyidae as defined by Wood include only the genera *Ischyromys*, *Titanotheriomys*, and *Pareumys*. Burke's Ischyromyidae (of 1935) apparently included Wood's Ischyromyidae, Cylindrodontidae, and part of his Sciuravidae.

[9] O. A. Peterson, *loc. cit.*, 1919.
[10] R. W. Wilson, Proc. Nat. Acad. Sci., vol. 21, no. 1, p. 31, 1935.
[11] J. J. Burke, Ann. Carnegie Mus., vol. 25, pp. 7, 12, 1935.
[12] A. E. Wood, *op. cit.*, p. 186, 1937.

However, Wood stressed the close relationship of all three of these families. Lastly, Burke in 1938 [13] in a paper describing *Pseudocylindrodon medius* assigned *Pseudocylindrodon* to the Cylindrodontidae and felt that "the rodent genera *Mysops* (as delimited by Wilson), *Pareumys*, *Pseudocylindrodon*, *Cylindrodon* and *Ardynomys* constitute a valid family assemblage." In the same paper he also says, "The dentition of the present species [i.e. *P. medius*] makes the nearest approach to that of the Eocene genus *Mysops* known among Oligocene rodents, and *Pseudocylindrodon medius* furnishes a most satisfactory link between *Mysops*, *Pareumys* and Oligocene cylindrodonts such as *Ardynomys* and *Cylindrodon*."

While the known specimens representing *Pareumys* are extremely fragmentary and leave much to be desired, it seems possible to outline somewhat more clearly than heretofore the affinities of Peterson's genus. It is obvious that *Pareumys* is not a murine. Neither can it be considered on present evidence as ancestral, genetically or structurally, to *Cylindrodon* or *Pseudocylindrodon*. This is particularly manifest in the light of characters shown by the upper dentition of *Pareumys* as compared with that in the Oligocene genera. The metaloph in the latter forms is apparently attached to the protocone much as in some of the upper cheek teeth of *Mysops*. At any rate, it is not of the incomplete type seen in specimens of *Pareumys*. Judging from the realignment of the metaloph and union of the metaconule to the posteroloph in advanced species of *Pareumys*, the upper Eocene genus is developing along different lines. The evidence of the lower dentition is essentially as stated by Burke.

If it is not possible to view *Pareumys* as structurally ancestral to the Oligocene cylindrodonts, it is even less possible to regard it as ancestral to *Ischyromys*. The pattern of the upper teeth separates it more decidedly from the latter, and the lower dentition in at least the advanced species also differs in a number of features which do not seem to be particularly intermediate between the Bridger forms and *Ischyromys*. On the whole, *Pareumys* is much more closely related to *Pseudocylindrodon* and *Cylindrodon* than to *Ischyromys*. The several species of *Ischyromys* exhibit considerable variation as regards certain characters, and characters of *Pareumys* are by no means constant. However, the following differences hold in general in distinguishing *Pareumys* of the Sespe from *Ischyromys:* (In *Ischyromys*) (1) $P\overline{4}$ less reduced in size, perhaps less obliquely set in ramus; (2) inferior molars with trigonid cusps more alternating, metaconid less marginal, metalophulid II stronger; (3) ectolophid not as high or prominent a ridge; (4) hypolophid less compressed, less prominently ridged—union with ectolophid generally at junction of ectolophid-hypoconid rather than slightly anterior to this point; (5) more rounded hypoconid; (6) posterolophid not elevated as in *Pareumys*—instead a sloping crest somewhat as in *Sciuravus;* (7) protoloph not as compressed; (8) metaloph complete;

[13] J. J. Burke, Ann. Carnegie Mus., vol. 27, pp. 255, 268, 1938.

(9) hypocone much better developed; (10) cingula of upper teeth not as high; (11) crowns of cheek teeth less flat-topped, probably less hypsodont; (12) inferior incisors narrower; and (13) masseteric fossa of ramus much less sharply defined.

So far as is known at present, *Pareumys* has apparently no known Oligocene descendants.[14] This is true of the advanced species, and probably also true for *P. grangeri* and *P.* (?) *troxelli*. Any Oligocene forms which might be derived possibly from these earlier species can be derived more readily from Bridger species.

Burke has stated [15] that *Pareumys grangeri* "forms an excellent link between *Pareumys milleri* Peterson and its Bridger relatives," i.e. *Mysops* sp. div. There can be little question but that a branch of the *Mysops* group of the Bridger gave rise to the upper Eocene genus *Pareumys*. Probably several different lines will be recognized eventually in the *Mysops-Pareumys* group, exhibiting various evolutionary trends. However, present material is such as to make a differentiation too unreliable for presentation.[16] Typical *Pareumys* represents a line in which the primitive attachment of metaloph to protocone is dissolved and the loph realigned, finally to become united strongly with the posteroloph. A small hypocone is acquired, but this element does not obscure the fundamentally tritubercular structure of the upper molars. In the lower dentition, the difference between height of trigonid and of talonid is equalized, and the connecting crests become higher and stronger. Trigonids and talonids become more nearly equal in width. The cheek dentition grows more hypsodont, and approaches a flat-topped condition. Apparently there is some increase in size of species.

The general systematic position of *Pareumys* among the early Tertiary rodent genera seems to be reasonably certain. The correct family name to be applied to the genus possibly is not. Clearly it should be placed in the same family as the genus *Mysops*. Moreover, *Pareumys* is more closely related to the typical cylindrodonts than to *Ischyromys*. Also, both it and *Mysops* are more closely related to the former group than either is to *Sciuravus*. The relationship of the genus may be expressed best perhaps by assigning it to the Cylindrodontidae if, as it seems, it is necessary to separate the cylindrodonts from *Ischyromys* and *Titanotheriomys* as a distinct family as recognized, for example, by Wood and more recently by Burke. Since *Mysops* and *Pareumys* are closely related, and the former is

[14] *Prosciurus lohiculus* bears a resemblance to *Pareumys* near *milleri* in attachment of metaloph to posterior cingulum. However, the union is accomplished by development of spurs rather than by a rotation of the metaloph. Nevertheless, it may be that certain of the high-crowned dentitions assigned to *Prosciurus* are in the cylindrodont line. Wood has suggested that a tooth from the Cypress Hills assigned by him to *P.* aff. *lohiculus* may be referable to *Ardynomys*.

[15] J. J. Burke, Ann. Carnegie Mus., vol. 25, p. 9, 1935.

[16] R. W. Wilson, Amer. Jour. Sci., ser. 5, vol. 35, pp. 214–217, 1938.

placed in the Sciuravidae by Wood, another assignment might be considered, namely to this family. The desirability of such an allocation rests in large measure on whether a horizontal or a vertical classification is preferable in view of our present lack of detailed knowledge of the history of the genera under consideration. Whatever the size may be of the taxonomic units involved, the writer feels that the distinctions observed between the upper dentitions of *Sciuravus* and *Mysops-Pareumys* are of real importance in a determination of affinities, and point to a closer phylogenetic relation of the latter to the cylindrodonts than to the contemporary *Sciuravus*.

Pareumys near *milleri* Peterson

FIG. 1. Right upper molar, No. 2215, loc. 150.
FIG. 2. Left upper molar, No. 2214, loc. 150.
FIG. 6. Fragmentary left ramus with $M\bar{1}$–$M\bar{2}$, No. 2210, loc. 150.

Pareumys sp.

FIG. 3. Left upper molar, No. 2224, loc. 207.
FIG. 7. Right $M\bar{3}$, No. 2219, loc. 202.
FIG. 10. Fragmentary right ramus with $M\bar{1}$–$M\bar{3}$, No. 2222, loc. 207.

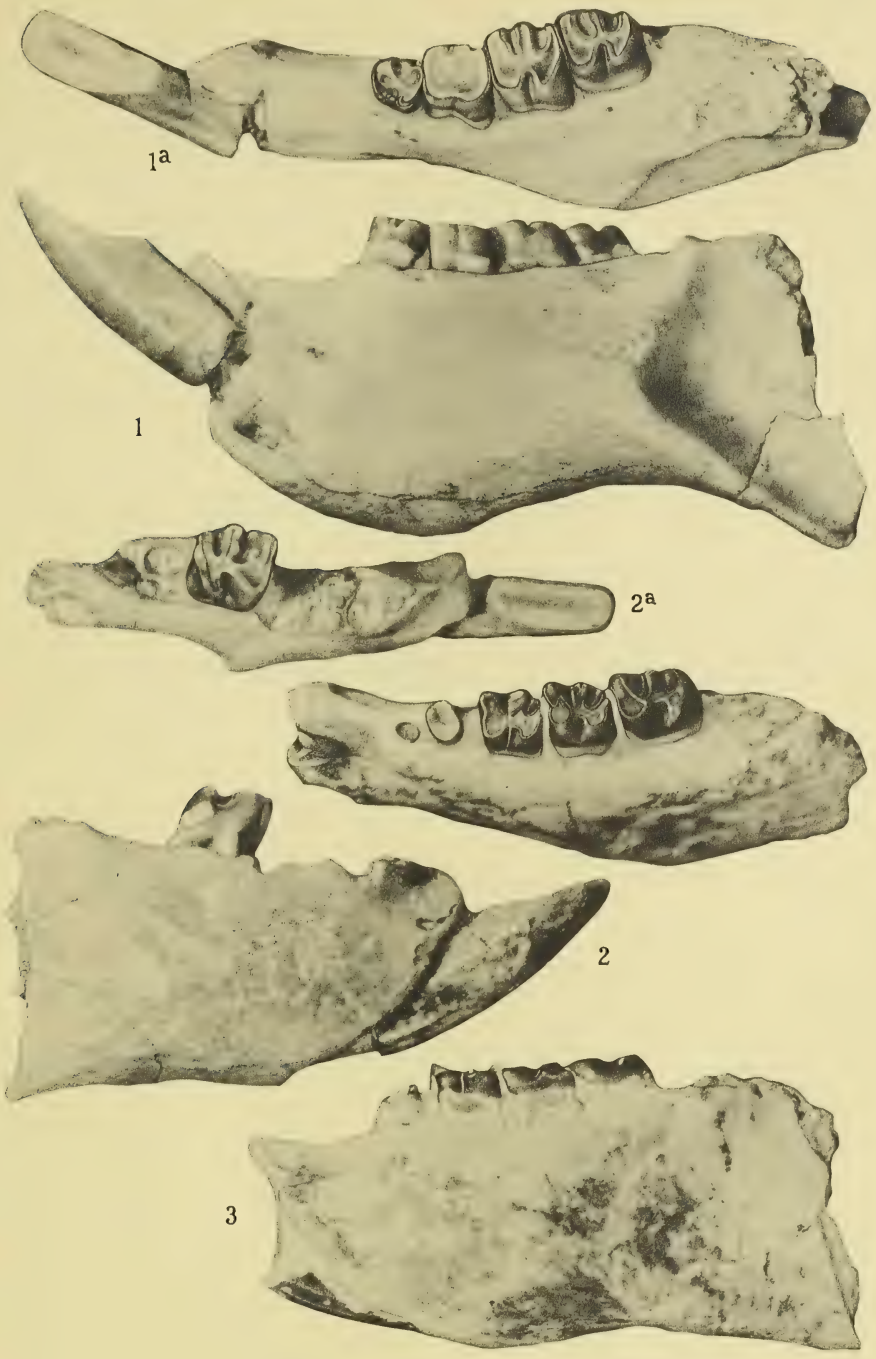
Pareumys (?) sp.

FIGS. 8, 8*a*. Fragmentary left ramus with $M\bar{2}$, No. 2221, loc. 202. Fig. 8, lateral view; fig. 8*a*, occlusal view.

Pareumys near *grangeri* Burke

FIG. 4. Left upper molar, No. 2230, loc. 249.
FIG. 5. Left upper molar, No. 2231, loc. 249.
FIG. 9. Right $M\bar{1}$–$M\bar{3}$, No. 2225, loc. 249.

Calif. Inst. Tech. Coll. Vert. Pale.
Sizes of all figures approximately $\times 6\frac{2}{3}$.
Locality 150, Sespe uppermost Eocene. Localities 202, 207, Sespe upper Eocene. Locality 249, Poway upper (?) Eocene.



Pareumys near *milleri* Peterson

Figs. 1, 1*a*. Left ramus with $\overline{P4}$–$\overline{M3}$, No. 2209, loc. 150. Fig. 1, lateral view; fig. 1*a*, occlusal view.

Pareumys sp.

Figs. 2, 2*a*. Right ramus with $\overline{M2}$, No. 2217, loc. 202. Fig. 2, lateral view; fig. 2*a*, occlusal view.

Pareumys near *grangeri* Burke

Figs. 3, 3*a*. Left ramus with $\overline{M1}$–$\overline{M3}$, No. 2226, loc. 249. Fig. 3, lateral view; fig. 3*a*, occlusal view.

Calif. Inst. Tech. Coll. Vert. Pale.
Sizes of all figures approximately × 5.
Locality 150, Sespe uppermost Eocene. Locality 202, Sespe upper Eocene. Locality 249, Poway upper (?) Eocene.

CONTRIBUTIONS TO PALEONTOLOGY

VIII

A NEW MIOCENE MAMMALIAN FAUNA FROM CALIENTE MOUNTAIN, CALIFORNIA

By Jack F. Dougherty

With seven plates and four text figures

[Issued June 27, 1940]

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A NEW MIOCENE MAMMALIAN FAUNA FROM CALIENTE MOUNTAIN, CALIFORNIA

INTRODUCTION

Fossil mammalian remains from the Caliente Mountain region, San Luis Obispo County, California (fig. 1), were first found by John B. Stevens in 1928 in red beds associated with basalt flows near Padrones Spring. The material, fragments of an antilocaprid jaw, was presented to the California Institute of Technology at that time. The importance of the Caliente Mountain marine section is emphasized by Reed and Hollister.[1] In their discussion[2] of the Caliente Miocene they state: "The great difference in facies of these beds permits the determination of the interrelation of mammalian, mollusk, and foraminiferal zones, a task that is not easy in many districts." The present study was undertaken, therefore, with a view to obtaining a mammalian fauna from the region and establishing its relations to the Miocene molluscan and foraminiferal zones. Furthermore, the discovery of the original material gave promise of finding additional types by which the relation of the vertebrate and invertebrate time scales for at least this stage of the Miocene might be established.

Field work and further collecting were carried on by the author during the fall, winter, and spring months of 1938–1939. For suggesting this problem and for valuable assistance and encouragement, the author is greatly indebted to Dr. Chester Stock. E. L. Furlong and Dr. R. W. Wilson have kindly tendered many helpful suggestions during the course of study. The author wishes to acknowledge gratefully the courtesy of J. E. Eaton, Dr. U. S. Grant IV, and Harry Allen of the University of California at Los Angeles, and their kind permission to use valuable data obtained by them in a study of the fossil molluscan faunas from this area. Dr. R. M. Kleinpell and W. D. Kleinpell furnished important information bearing on the correlation of the known foraminiferal zones with the vertebrate horizon. Dr. W. S. W. Kew gave helpful suggestions concerning the field mapping. The illustrations have been prepared by David P. Willoughby. The aerial photographs (plates 1–3) were taken by Fairchild Aerial Surveys, Inc. During the progress of the investigation kind permission was granted by Mr. Washburn to carry on field work within the boundaries of the Washburn Ranch.

LOCATION AND OCCURRENCE

The area in which the fossil material was obtained lies on the northeast flank of the Caliente Range in San Luis Obispo County, California (fig. 2). Caliente ridge forms the western boundary of Carrizo Plain and

[1] R. D. Reed and J. S. Hollister, Structural evolution of southern California, p. 80. Amer. Assoc. Petrol. Geol., 1936.

[2] *Ibid.*, p. 82, 1936.

overlooks the Cuyama River Valley to the southwest. The fossiliferous beds are exposed in badlands on the back slope of the dissected eastern limb of the main Caliente Mountain anticline. The fossil localities are distributed along the strike of the beds for some 5 miles northwest of a point ½ mile southeast of Padrones Spring. These occurrences lie in sections 25, 26, and 27 of T. 11 N., R. 26 W., and in sections 31 and 32 of T. 11 N., R. 25 W., McKittrick Quadrangle, California.

The strata containing the vertebrate fossils represent a series of highly colored sediments, associated with four or five basaltic flows, intercalated

FIG. 1. Outline map with rectangular areas showing location of Caliente Range with respect to the Merychippus zone near Coalinga, California.

in Temblor marine sandstones. The fossil localities are scattered throughout the land-laid sediments and are closely associated with the basic extrusives. The highest stratigraphic positions of the fossil vertebrates are between the Main Basalt flows and the "upper Miocene" shale, below the Main Basalt and above the Upper Triple Basalt. Fossil remains occur also in very compact, fine-grained tan and red siltstones between the lower and middle and between the middle and upper members of the Triple Basalts. The next to lowest occurrence is in medium-grained white sand, with interbedded greenish clay lenses, that lies approximately 50 feet below the lowest Triple Basalt flow.

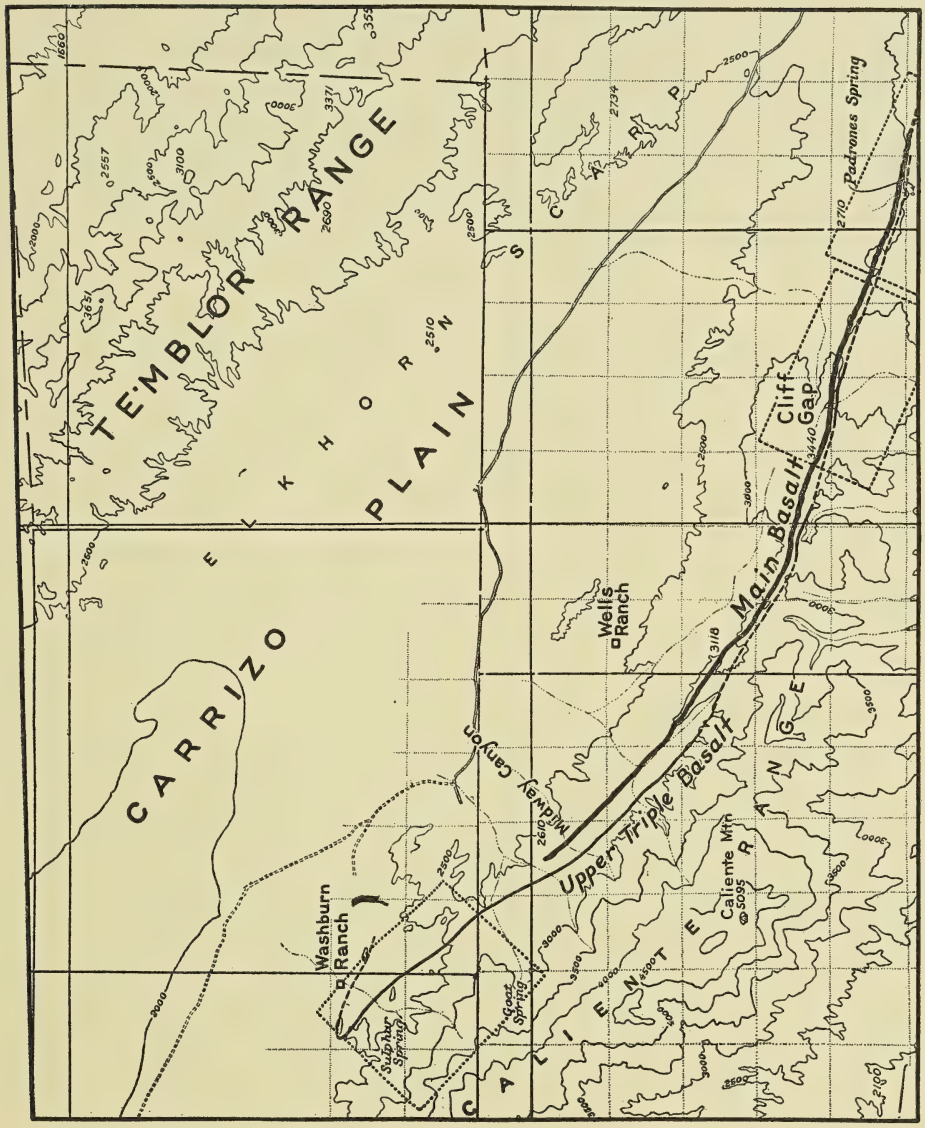


FIG. 2. Map of southeastern portion of U. S. Geological Survey McKittrick Quadrangle, showing location and distribution of areas yielding Miocene mammalian, molluscan, and foraminiferal faunas along lateral extent of marker basalt flows, Caliente Mountain, California.

The fossil material, in all but the latter horizon, consists of isolated bones and teeth, and its preservation is fragmentary. Only at one locality were mammalian remains found in fair abundance in the white sands and greenish clays. This site, C.I.T. Vert. Pale. Loc. 315, yielded a badly crushed merycoidodont skull and a number of isolated teeth and limb bones of merychippine horses. Limb elements are poorly preserved, and are water-worn and abraded. The tooth material is in a better state of preservation, but individual teeth tend to break apart when removed from the matrix.

The lowest vertebrate horizon lies approximately 1400 feet stratigraphically below the Lower Triple Basalt horizon, locality 325. This horizon contained fragmentary bones and teeth referable to an immature merycoidodont, probably similar to *Merychyus calimontanus*, n. sp.

MODE OF ACCUMULATION

The presence of fossil remains of land animals in the upper portion of a marine invertebrate-bearing sandstone series calls for a discussion of the probable mode and site of deposition of the vertebrate material. As is shown on the chart of columnar sections, figure 3 (p. 122), and as stated in the discussion of the stratigraphy, the mammal-bearing horizons are associated with deposits containing remains of littoral marine organisms such as *Ostrea* and *Turritella*. In all cases the mammals and invertebrates occur in separate beds, but frequently the deposits containing them lie immediately adjacent to one another. This relationship suggests an accumulation disturbed by diastrophic movements which brought about a rhythmic interfingering of nonmarine and littoral marine strata. Along a given line of traverse the stratigraphic sequence from bottom to top may include the following: oyster reef, mammal remains, basalt, mammal remains, basalt, oyster reef, basalt, mammal remains, oyster reef, mammal remains. Apparently during the period of this deposition rapid transgressions and regressions of the sea were taking place, with extrusions of basaltic material accompanying the laying down of marine sands, silts, and clays.

The fine sandy siltstones of reddish color, containing abundant merycoidodont remains, may have been laid down as flood-plain deposits or as loess. It seems likely that such silts and clays represent deposits formed by a slow-flowing, aggrading stream. A similar type of deposition has been postulated by W. D. Matthew [3] as accounting for the entombment and preservation of merycoidodont remains in the White River beds. The medium-fine sand and greenish clay lenses as well as the coarse sandstones found in the Caliente section may represent stream-channel deposits, although some of the coarse sands may be marine in origin, in view of their wide lateral extent. The proximity of oyster-bearing silts suggests that the flood-plain silts and stream-channel sands were deposited sufficiently close to the mouth of a stream to permit periodic interfingering of marine littoral accumulations.

[3] W. D. Matthew, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 22, p. 23, 1932.

The abraded and waterworn state of the fossil limb elements in the sand and clay lenses supports the view of a stream-channel accumulation, and similarly the scattered, but sometimes well-preserved, merycoidodont remains in the red silts suggest burial under flood-plain conditions.

FAUNA OF THE CALIENTE RED BEDS

The mammalian assemblage from the Caliente Range is incomplete, and consists entirely of herbivores. Further collecting doubtless will bring to light better material and add some representation of the carnivores. The following species are recognized:

Perissodactyla:
- Rhinocerotid sp.
- Hypohippus (?) sp.
- Parahippus (?) sp.
- Merychippus carrizoensis, n. sp.
- Merychippus stevensi, n. sp.

Artiodactyla:
- Merychyus calimontanus, n. sp.
- Ticholeptus (?) sp.
- Merycoidodont sp. *a*
- Merycoidodont sp. *b*
- Camelid (?) sp.
- Dromomeryx (?) sp.
- Antilocaprid sp.

Chelonia:
- Testudinate remains

ENVIRONMENT OF FAUNA

The environmental conditions which prevailed during the existence of the Caliente Miocene vertebrate fauna may be best understood perhaps from a study of the horses and merycoidodonts. The most common type of merychippine horse found in this horizon has very low-crowned and almost wholly uncemented teeth; a type of dentition ill adapted to the gritty grasses of the open plains. Similarly, the anchitheriine horses, *Parahippus* and *Hypohippus*, with brachydont dentition and relatively broad feet, were probably not typical plains-dwellers. These forms suggest a forest or glade environment and a humidity greater than that which characterizes the region today. A less common merychippine horse in the fauna has teeth that are higher-crowned and more heavily cemented than in the species mentioned previously and indicate a better adaptation in the direction of grazing on open plains. These types suggest an environment in which wooded areas are adjacent to or interspersed with grasslands.

The rhinocerotid may be regarded as a type living under similar environmental conditions. Bode [4] calls attention to the fact that the modern species of rhinoceros feed on grasses and on the leaves of small trees and shrubs.

[4] F. D. Bode, Carnegie Inst. Wash. Pub. No. 453, paper VI, p. 78, 1935.

The large number of merycoidodonts occurring in the fauna indicates a habitat favorable to their widespread development. Matthew [5] concludes from the occurrence of merycoidodonts and from a study of the characters of their teeth and limbs that these mammals lived wholly in the open and had acquired a grazing habit. The light, long-limbed *Merychyus* stock in particular was well adjusted to life on the open plains. It is interesting to note that the fauna from the Merychippus zone lacks any representation of the Merycoidodontidae, although some of the remaining faunal elements are comparable to those in the Caliente assemblage. Thus there appears to be some suggestion that the fauna of the Merychippus zone was not one dwelling typically on the plains.

The Caliente fauna regarded as a unit suggests the presence of an open plains environment adjacent to the flood plain of some stream, with forested areas near at hand.

STAGE OF EVOLUTION OF FAUNA

The small horse, *Merychippus carrizoensis*, is related to *M. insignis primus* of the Sheep Creek beds of Nebraska, and suggests a middle Miocene age for the Caliente fauna. Furthermore, the relation of *M. stevensi* to *M. isonesus* of the Mascall in stage of evolution, as indicated by a comparison of the dentition, likewise suggests an age not later than upper Miocene. Although the actual number of collected specimens referred to the Equidae is small, the relative abundance of teeth of one type of horse and the scarcity of those of another reflect to some degree the representation of these forms in the fauna. The relatively frequent occurrence of a small, primitive *Merychippus* and the presence of a large, more advanced member of this genus may be taken to indicate a stage slightly earlier than the Mascall and later than the Sheep Creek. *Merychippus isonesus* is the characteristic species in the Mascall, while the smaller and more primitive *M. relictus* and *M. severus* are not so abundantly represented. Exactly the reverse is the case with regard to presence of primitive and more advanced equid species in the Caliente fauna. *Merychippus insignis primus* of the Sheep Creek fauna appears to be somewhat more primitive than the Caliente species. Hence, the Caliente fauna may be regarded as more advanced in the presence of this new small species as well as of the advanced form *M. stevensi*.

The two anchitheriine genera, *Hypohippus* and *Parahippus*, in the Caliente assemblage are characteristic of the middle Miocene, particularly in their association with large and small merychippine forms. The material referred to these two genera is too fragmentary to permit very detailed determinations of relationship. The species of *Parahippus* is smaller and apparently more primitive than *P. brevidens* or *P. avus* of the Mascall, and therefore suggests a stage somewhat earlier than the Mascall Miocene.

The rhinocerotid material is too fragmentary to assist in establishing faunal relationships.

[5] W. D. Matthew, *op. cit.*, p. 30, 1932.

The characters exhibited by the merycoidodont remains do not furnish a satisfactory basis for determining the stage of evolution of these mammals. However, the relative abundance of merycoidodonts in the Caliente fauna is noteworthy, especially in view of the fact that they appear to be more characteristic of the middle than of the upper Miocene.

Dromomeryx (?) sp. may represent a lower middle or upper Miocene age, but the association of this genus with anchitheriine and merychippine horses frequently occurs in middle Miocene faunas.

RELATIONSHIPS OF FAUNA

Pacific coast province. Among Miocene faunas of the Pacific coast, only that of the Merychippus zone on Domengine Creek, North Coalinga district, shows close relation to the Caliente assemblage. There are no determinable species in common between these two faunas, although a number of genera found in the one assemblage occur also in the other. The Caliente species of horse are less advanced than *Merychippus californicus* and *M. brevidontus*, and the latter are related to the *M. isonesus* rather than to the *M. insignis* group. The *Parahippus* (?) sp. appears to be much less advanced than the Coalinga *P. brevidens*. Absence of merycoidodonts in the Coalinga assemblage may indicate a more advanced stage for the latter fauna or the presence of unfavorable environmental conditions. It appears probable that ecologic conditions were among the deciding factors unfavorable to the representation of these oreodonts. The remainder of the fauna does not exhibit sufficient characters from which to make detailed statements concerning relationships.

Great Basin province. The Tertiary assemblages of the Great Basin province which show closest resemblance to the Caliente fauna are the Mascall, Skull Springs, and Virgin Valley faunas, all nearly related. The Mascall shows greatest resemblance to the Caliente. *Merychippus carrizoensis*, n. sp. is closely related in stage of evolution to *M. severus*, *M. relictus*, and *M. insignis*, although slightly more primitive. *Merychippus stevensi*, n. sp. is comparable in stage of development to *M. isonesus* although certainly distinct specifically. Because of lack of sufficient material the comparison of the anchitheriine horses from the Caliente beds with those from the Mascall is difficult. However, *Parahippus* (?) sp. is smaller and apparently more primitive than *P. avus* or *P. brevidens*. The merycoidodont genera and species are distinct and offer no basis for comparison, other than that they are abundant or represented in both faunas. The small camelid from the Caliente may resemble *Miolabis*, a genus occurring in the Mascall. *Dromomeryx* (?) sp. is too poorly represented to give more than an indication of affinity with *D. borealis* of the Mascall.

Great Plains province. The most nearly related Miocene vertebrate fauna from the Great Plains province is apparently the Sheep Creek.[6] This fauna

[6] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, art. 2, 1924.

is slightly less advanced than the Caliente assemblage, but possesses comparable forms. Presence of an advanced merychippine type, *M. stevensi*, n. sp., in the Caliente fauna and absence of any comparable species in the Sheep Creek beds suggest that the former assemblage is more advanced than the Sheep Creek. *Merychippus carrizoensis*, n. sp. is closely related to the Sheep Creek form, and the differences are regarded as of specific value. The artiodactyl forms *Merychyus* and an antilocaprid occur in both assemblages. However, no specific comparisons can be made owing to the incompleteness of the material and the inadequateness of published descriptions.

Atlantic and Gulf coast province. The vertebrate faunas in this province comparable to the Caliente are the upper Hawthorn of Florida [7] and the "Navasota" [8] assemblage of Texas. The former assemblage is somewhat like the Caliente in state of preservation and in its constituency. The upper Hawthorn is less advanced than either the Caliente or the Sheep Creek, and its age is probably lower middle Miocene. *Merychippus gunteri* of the upper Hawthorn is more primitive than *M. insignis primus* or *M. carrizoensis*, n. sp., although very similar to these forms in size and in characters of the dentition. *Merychippus stevensi*, n. sp. is much more advanced than any species of *Merychippus* from the Hawthorn. The merycoidodonts cannot be compared directly because of their fragmentary character. *Dromomeryx* is present in both faunas, but again the materials do not permit adequate comparison.

The Miocene assemblage from Texas contains two species of small merychippine horse and one larger merychippine type. The fauna appears to be a mixed assemblage, containing *Miohippus*, *Parahippus*, and *Merychippus*, but representatives of the latter genus seem very close to those from the Caliente red beds. *Merychippus vellicans* Hay and *M. socius* Hay may be comparable to the smaller *Merychippus* of the Caliente area in stage of evolution, and *M. francisi* Hay is similar to the large *Merychippus*. The remaining forms in the Texas assemblage appear to have been derived from several different horizons, although *Parahippus* and *Dromomeryx* are recorded from the same locality as the Merychippi. At present this fauna is not sufficiently well known to permit adequate comparisons, although it may be stated that at least some of the "Navasota" forms are comparable in age to these of the Caliente beds.

STRATIGRAPHIC POSITION OF THE CALIENTE MAMMALIAN FAUNA IN TERTIARY MARINE SERIES OF CALIFORNIA

The oldest exposed strata in the core of the Caliente Mountain anticline are a series of sparsely fossiliferous black shales referred to the Oligocene.[9]

[7] G. G. Simpson, Florida State Geol. Surv. Bull. No. 10, p. 14, 1932.
[8] O. P. Hay, Proc. Biol. Soc. Washington, vol. 37, pp. 1–20, 1924.
[9] R. D. Reed and J. S. Hollister, Structural evolution of southern California. Amer. Assoc. Petrol. Geol., 1936.

These shales may be Eocene or lower Miocene, as the paleontologic evidence is not altogether satisfactory. Overlying this shale series is a thick accumulation of lower Miocene marine shales and sandstones carrying Vaqueros fossils. These deposits grade upward into strata, dominantly marine sandstones, which carry middle Miocene Temblor fossils. Above a thick transitional series of beds from which both Vaqueros and Temblor faunas have been obtained are sandstones containing middle and upper Temblor mollusks. The upper portion of the Temblor becomes nonmarine and yields a mammalian fauna from beds closely associated with several basaltic flows. This upper portion of the middle Miocene section consists dominantly of red beds with basalt flows, but some interbedded marine sands are also present and these contain littoral marine mollusks.

Overlying the basalts and red beds is a brown silty shale a few hundred feet thick. It is apparently nonmarine, but no fossils were found. A thick series of coarse sands and silts make up the "upper Miocene" strata at the top of the section, overlying the shale. No identifiable fossils are recorded from these, although some unidentifiable bone fragments were found near its base by H. D. Curry and R. D. Reed.[10] An upper Miocene age for these deposits is suggested because of their position above the Temblor. However, it is quite possible that the stratigraphically highest portion of these sediments may extend in time into the Pliocene.

The change in types of sediment and fauna in the Miocene section of Caliente Mountain has been recognized by Reed and Hollister.[11] They state: "The Caliente Mountain section is marine in the Lower Miocene parts, littoral above lower Middle Miocene, and non-marine throughout the several thousand feet of beds belonging to the upper Middle and Upper Miocene. Toward the southeast Lower Middle Miocene grade into littoral and then non-marine facies. Toward the northwest, on the other hand, all members become marine, and most of the Lower and Middle Miocene becomes foraminiferal, commonly siliceous, shale."

These stratigraphic relations make possible the correlation of foraminiferal, molluscan, and mammalian faunas of the Miocene in the Caliente Mountain area. In establishing this correlation certain persistent basalt flows were found to serve as convenient marker beds (fig. 2). A description of the individual sections will bring out the relations of these faunal stages to each other.

Padrones Spring and Jerd Spring area. As is shown by the aerial photograph, plate 1, there are two principal basalt flows, the Main Basalt and the Lower Basalt. The former consists of two or three individual flows separated by clastic tuff and breccia. The total thickness of the flows is approximately 100 feet. This group of flows forms the resistant stratum behind which are eroded the small basinlike badlands of Jerd Spring and

[10] R. D. Reed, personal communication.
[11] R. D. Reed and J. S. Hollister, *op. cit.*, p. 82, 1936.

Padrones Spring. Above the Main Basalt is exposed some 700 feet of coarse red massive sandstones and interbedded red siltstones. These beds dip under the alluvium of the valley floor to the northeast. Southward along the strike the contact of these beds with the white and reddish coarse sandstones of "upper Miocene" age is exposed. A thick section of the latter sediments is seen in the area reaching from the Main Basalt to the San Andreas Rift. Southeast of Jerd Spring are numerous basalt flows and poorly dissected red beds.

The only fossil vertebrate, found in beds overlying the basalt and representing a member of the Antilocapridae, occurs some 300 feet above the upper contact of the Main Basalt, locality 170.

Below the Main Basalt at Jerd and Padrones Springs is a series of coarse red sandstones, green tuffaceous beds, and chocolate and tan siltstones, in which occur remains of *Merychyus calimontanus* and of a rhinocerotid at localities 313 and 312. These strata are folded, the folding having been sufficiently intense to produce reverse dips of the Main Basalt. To the southwest almost vertical dips of the basalt can be found in places, but these return to the normal 45° NE. east and west of this area. Below these sandstones and silts exposed in the badlands of Padrones Spring are several unmapped basalt flows that may be the southeastward continuation of the Triple Basalts of the Cliff Gap and Wells Ranch areas.

Approximately 2500 feet below the Main Basalt is the Lower Basalt, forming the southern boundary of the undissected area in back of Padrones Spring. This flow is approximately 50 feet thick and does not extend laterally into the Cliff Gap area, although the horizon may be traced into that section by means of a massive white sandstone bed which continues to the west after the basalt has thinned and disappeared. One hundred feet below the Lower Basalt is the locality of the lowest occurring recognizable vertebrate remains, locality 325. The material found here consists of teeth and limb fragments of an immature merycoidodont. This form is probably different from the *Merychyus* described from Jerd and Padrones Springs, but the material is too scrappy to permit positive identification. Unidentifiable fragments of bone were also found 200 feet farther down in the section at locality 325P. It would appear from the position of these lowermost fossil localities that the latter belong in the middle Temblor or in the older marine invertebrate horizons. If this is actually the case, a faunal difference may exist between the vertebrates found in the sediments associated with the Main Basalt and the types occurring in the lower part of the section. The fossil material available does not give evidence of a difference, owing to its fragmentary character and scantiness. Until such time as they may be shown to be separate, all the fossil vertebrates occurring in a stratigraphic thickness of 3500 feet are regarded as belonging to a unit fauna.

The only invertebrate fossil found in this area is a fragment of a *Turritella* from the Padrones Spring badlands. J. E. Eaton [12] reports the presence of a zone containing *Turritella carrisaensis* in the area.

Cliff Gap area. West along the strike of the basalt flows from Jerd Spring and Padrones Spring is the Cliff Gap area (plate 2). This region yielded the most important mammalian fossil material and also demonstrated the close association of fossil vertebrates and invertebrates. The Main Basalt persists and continues westward into the Wells Ranch area. Overlying the Main Basalt are 1300 feet of coarse red sandstones that yielded no fossils. Above these red beds are unfossiliferous brown shale and a coarse sandstone and silt series which may be upper Miocene in age. These sediments are involved in the partly overturned Wells syncline.

Below the Main Basalt are coarse red sandstones that outcrop in the Padrones Spring area, but interbedded with their lower portion and underlying them is a series of three or four thin basalt flows, named the Triple Basalts by Allen and Anderson.[13]

Figure 3 shows the columnar sections in the four critical areas and a correlation of the several basalt flows.

Three hundred feet of coarse red sandstones occur between the Main Basalt and the Upper Triple Basalt. No vertebrate fossils were collected, although the sediments represent the equivalent of sandstones containing *Merychyus* and rhinocerotid in the Padrones Spring badlands. The Upper Triple Basalt underlying these sandstones is discontinuous, but becomes continuous farther to the west. The flow in this area averages about 40 feet in thickness. Below the Upper Triple are 150 feet of red sandstones and red and buff siltstones. Between the Upper and Middle member of the Triple Basalt in the Cliff Gap sections occurs an intercalated basalt flow of limited extent which may be designated as a substage of the Upper Triple. Seventy feet above this minor flow occur remains of *Hypohippus* (?) sp. at locality 323. Thirty-five feet above this minor flow and 1800 feet west along the strike, in a buff siltstone, occur remains of *Merychippus stevensi*, *Parahippus* sp., and limb elements referred to *Hypohippus* (?) sp. Twenty-five feet above the minor flow and below locality 323 is an oyster reef carrying an unidentified species of oyster.

The minor flow exhibits much weathered "pillow" structure. The outer surfaces of the "pillows" appear to have been chilled and are semivitreous. Limonite and gypsum veinlets fill numerous fractures in the basalt. The structure and appearance of this section in the vicinity of the subsidiary member of the Middle Triple contrasts strongly with the vesicular, dense black, and relatively unweathered basalts of the remaining flows. The characters of this flow suggest that it was laid down in the presence of water

[12] J. E. Eaton, personal communication.

[13] H. B. Allen and I. Anderson, A stratigraphic study of the Caliente Mountains Miocene, San Luis Obispo County, California. Unpublished thesis, Department of Geology, University of California at Los Angeles, 1938.

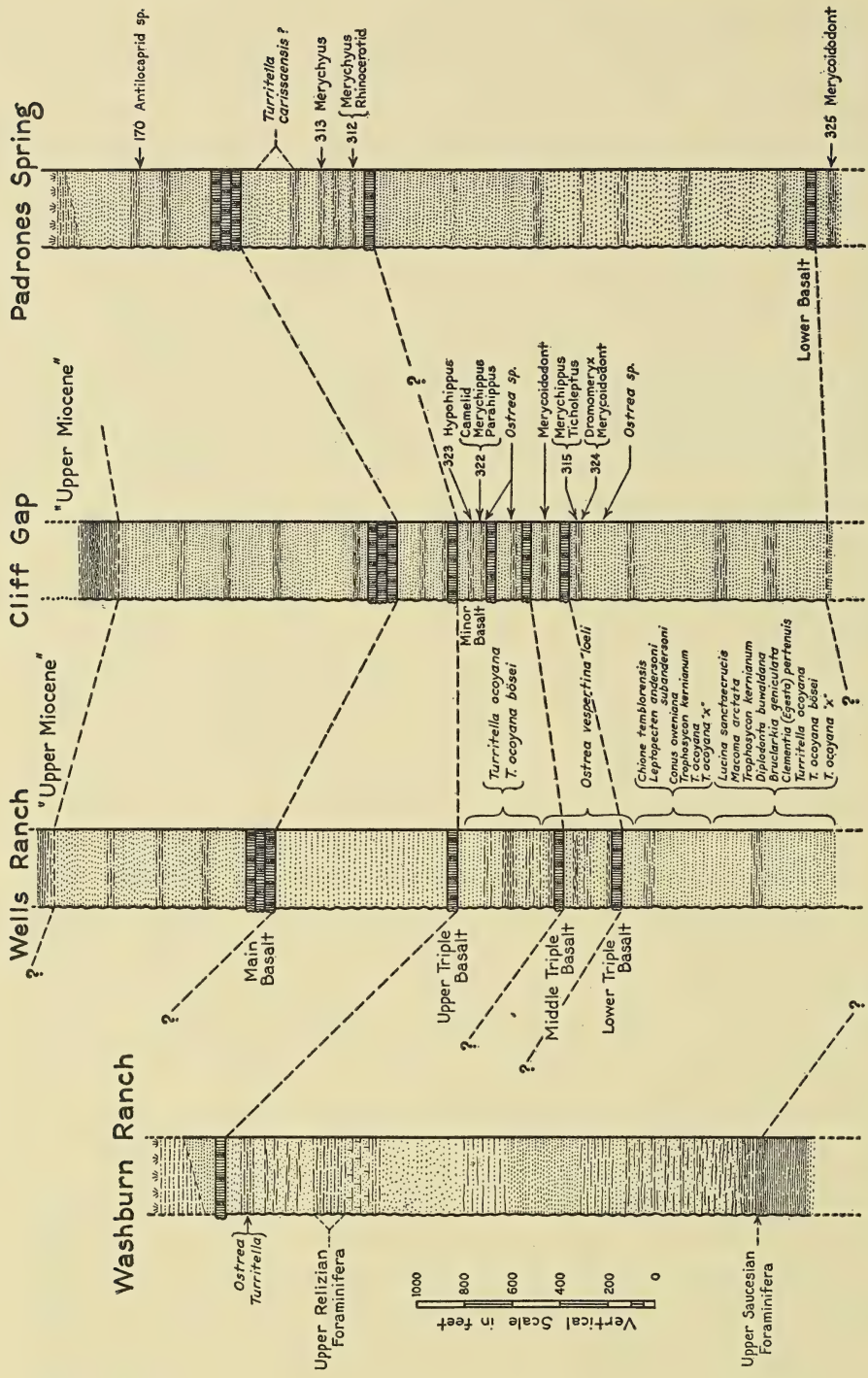


FIG. 3. Columnar sections showing stratigraphic relations of Miocene vertebrates and invertebrates and their position with reference to marker basalt flows, Caliente Mountain, California.

vapor, if not subaqueously. Its presence so close stratigraphically to the oyster reef is suggestive. This basalt flow is from 20 to 50 feet thick and extends laterally for approximately 3700 feet, disappearing to the east and west of this locality.

Below the minor flow are 120 feet of sandstones and silts, which overlie the Middle Triple Basalt. Near the Middle Triple occurs another oyster reef characterized by a species of oyster which appears to be identical with that found in the upper reef. The underlying Middle Triple Basalt is about 60 feet thick. Below this basalt are 140 feet of tan and red siltstones and a few massive beds of sandstone. A few fragmentary remains of merycoidodonts were found in the red silts.

The Lower Triple Basalt flow underlying these sediments is 50 feet thick. Below this flow is an uninterrupted series of sandstones and shales that change downward in the section from reddish to yellow and buff color. The red beds become less numerous, although they continue to occur down in the section for several thousand feet. Below these deposits are found sediments containing marine Temblor and Vaqueros fossils. Fifty feet below the Lower Triple are fossil localities 315 and 324. Locality 315 yielded the major part of the *Merychippus* material as well as the poorly preserved skull of the merycoidodont *Ticholeptus* (?) sp. At approximately the same stratigraphic level 4000 feet west along the strike is locality 324, which yielded several teeth referred to merycoidodont sp. *a* and *Dromomeryx* (?) sp. Below this horizon for a distance of 150 feet is another persistent oyster reef, and the oysters found here are again similar to those of the upper reefs.

Thirteen hundred feet below the Lower Triple Basalt is a massive buff sandstone bed that marks the lateral extension of the horizon of the Lower Basalt flow of the Padrones Spring and Jerd Spring area. No vertebrates were found this low in the section. It appears probable that the sediments adjacent to this horizon change from nonmarine to marine along the strike from the Padrones Spring section to the Cliff Gap section. Tracing this lowest of the vertebrate horizons between Padrones Spring and the Wells Ranch enables one to establish the position of the horizon with respect to the invertebrate zones of the Wells Ranch section.

Locality 324 is the westernmost of the vertebrate occurrences, although the Main and Triple Basalt flows continue farther westward. The reddish-colored sediments also continue westward into the Wells Ranch area, but invertebrate faunas replace the vertebrate assemblages.

Wells Ranch area. The Wells Ranch section containing the basalt lies 6 miles northwest along the strike of the lavas from the Cliff Gap section. The following data on the stratigraphy and paleontology of the area are derived from a thesis by Allen and Anderson [14] and from personal discussions with Dr. U. S. Grant IV and Mr. Harry Allen. A portion of the Wells

[14] H. B. Allen and I. Anderson, *op. cit.*, 1938.

Ranch columnar section is reproduced here (fig. 3) with the kind permission of J. E. Eaton, Dr. Grant, and Harry Allen. The section shows the stratigraphic relations of the basalt flows and the sediments containing the upper and middle Temblor invertebrate zones.

The Main Basalt is 150 feet thick in this area, and the overlying red beds have thinned some 300 feet from their thickness near Cliff Gap. The thickness of the sediments underlying the Main Basalt is three times as great as in the Cliff Gap area. These dominantly nonmarine deposits yielded no vertebrate fossils, though invertebrate fossils occur in marine wedges. The Triple Basalts retain the same thickness that they have to the southeast, although the intercalated sediments are thicker in this section. Yellow and buff sandstones are dominant in the interbedded sediments, while the red beds are more or less restricted to the section above the Upper Triple Basalt and below the "upper Miocene" shale.

One vertebrate fossil, a portion of a lower horse tooth, was found by Dr. U. S. Grant below the Main Basalt near Leaning House Gap. This tooth belongs to an advanced *Pliohippus* or possibly an *Equus*-like form. It belonged to a very high and straight-crowned tooth, much larger than the teeth of *Merychippus* found in the sediments of the Cliff Gap area. It cannot have been derived from the red beds associated with the Basalts and the Temblor invertebrates, and probably came from late Tertiary or Quaternary terrace deposits that cover portions of the area adjacent to Wells Ranch.

As is shown in figures 2 and 3, the correlation of the Triple Basalts and Main Basalts respectively between the Wells Ranch and Cliff Gap areas enables a time relation to be established between the sediments and invertebrates in the former area and the deposits and vertebrates of the latter region. The position of *Hypohippus* (?) sp., *Merychippus stevensi*, and *Parahippus* (?) sp. is stratigraphically equivalent to the upper zone of the upper Temblor as recognized by Grant and Allen. Similarly, *Merychippus stevensi*, *M. carrizoensis*, *Ticholeptus* (?) sp., merycoidodont sp. *a*, and *Dromomeryx* (?) sp. are stratigraphically equivalent to the underlying zone of the upper Temblor. As stated in the section on the relationships and stages of evolution of the fauna, the vertebrates suggest a middle Miocene age, intermediate between Mascall and Sheep Creek. The correlation chart, figure 4, shows the correspondence in age of these sediments associated with the basalts, as given independently by the invertebrate and vertebrate assemblages.

By tracing a buff sandstone bed, the horizon of the Lower Basalt of the Padrones and Jerd Springs section appears to be stratigraphically close to the base of the lowest zone of the Wells Ranch area as shown in the columnar sections, figure 3. This would indicate that the Lower Basalt horizon and the merycoidodont sp. *b* of locality 325 are probably the correlative of the middle Temblor. The fossil material from this horizon does not furnish a basis for determining the relation of this merycoidodont to *Merychyus*

calimontanus from the sediments associated with the Triple and Main Basalts.

Washburn Ranch area. This area lies 5 miles northwest of the Wells Ranch section and 13 miles northwest of Padrones Spring and Jerd Spring (plate 3). The Main and Triple Basalt flows are well exposed in the Wells Ranch section, but 1 mile northwest of Black Rock Ridge, near the mouth of Midway Canyon, the Main Basalt thins and disappears below the valley alluvium. The Upper Triple Basalt continues northwesterly into the Washburn Ranch section, but its companion flows, the Middle and Lower Triple Basalts, thin out and disappear in the vicinity of Midway Canyon. In this distance along the strike of the Upper Triple Basalt the red beds below are replaced by white and buff sandstones and calcareous shales. Above the basalt a few tens of feet of red beds persist along the strike into the Washburn Ranch.

It becomes evident therefore that an easily recognizable stratigraphic unit, the Upper Triple Basalt (fig. 2), can be traced for 10 miles from the vertebrate fossil occurrences of the Cliff Gap area through the section containing invertebrate fossils in the Wells Ranch area into the Washburn Ranch region, where foraminiferal shales occur. Thus the marker basalt flow permits a stratigraphic correlation of the beds containing molluscan, vertebrate, and foraminiferal assemblages in this portion of the Caliente Mountain Miocene.

Several years ago R. M. Kleinpell, W. D. Kleinpell, and J. S. Hollister [15] collected a Gould shale foraminiferal fauna in calcareous shales east of Sulphur Spring Creek. The locality, No. 1772 L.S.J.U., lies on the Washburn Ranch property in the near vicinity of the Upper Triple Basalt. In the aerial photograph of this area (plate 3) the Upper Triple Basalt is shown along the flanks of the ridges that lie immediately southwest of the valley under cultivation, south and west of the Washburn Ranch house. The small alluviated valley lies in the trough of a syncline, and the Upper Triple Basalt curves around the northern nose of the structure and is exposed immediately southwest of the ranch house as well as along the northeast rim of the valley. The nose of the syncline lies approximately 1 mile northwest of Sulphur Spring Creek.

From the locality description and information furnished by W. D. Kleinpell one may judge that the location of the foraminiferal fauna is in the valley now under cultivation. However, it is possible to give a maximum figure of 600 feet as the stratigraphic distance between this foraminiferal horizon and the Upper Triple Basalt which lies above it. It is quite probable that the whole series of beds between the basalt and the known locality are upper Relizian.

Southeast of the area which yields the upper Relizian foraminifera, near Goat Spring, additional foraminiferal assemblages were obtained. A fauna

[15] R. M. Kleinpell, Miocene stratigraphy of California, p. 73. Amer. Assoc. Petrol. Geol., 1938.

collected by J. E. Eaton and listed by Cushman and Laiming [16] is described as lower Saucesian. Further collecting in the vicinity of Goat Spring by Allen and later by the writer furnished assemblages having upper Saucesian affinities.

Saucesian foraminifera from Goat Spring, Caliente Range

1. Sample collected by J. Eaton at Goat Spring.
2. Sample G-1, Goat Spring.
3. Sample F-2, collected by Harry Allen, Goat Spring.

Forms present	1	2	3
Clavulina patens Cushman and Laiming	x		
Gaudryina cf. flintii Cushman	x		
Gaudryina triangularis Cushman	x		
Haplophragmoides trullissata (H. B. Brady)	x		
Cibicides floridanus (Cushman)	x	x	
Robulus aff. simplex (d'Orbigny)	x	x	x
Nonion costifera (Cushman)	x	x	x
Nonion incisum (Cushman)		x	
Uvigerinella obesa Cushman	x	x	x
Uvigerinella obesa impolita Cushman and Laiming	x	x	x
Uvigerinella californica ornata Cushman			x
Siphogenerina transversa Cushman		x	x
Plectofrondicularia miocenica Cushman		x	
Dentalina sp.		x	x
Nodogenerina advena Cushman and Laiming			x
Buliminella subfusiformis Cushman		x	x
Buliminella curta Cushman		x	x
Pulvinulinella parva Cushman and Laiming		x	x
Bolivina advena striatella Cushman		x	
Bolivina brevior Cushman		x	x
Bolivina cf. marginata Cushman		x	

Samples G-1 and F-2 were prepared and the forms determined by the writer. Boris Laiming and H. L. Driver kindly checked the determinations. The apparent absence of arenaceous forms in these two samples and presence of species dominant in the post-Saucesian Miocene of California are indicative of assemblages from the uppermost zones of the Saucesian in the type section. Eaton's assemblage is more typical of the lower Saucesian in that arenaceous forms are dominant.

The upper Saucesian foraminifera were obtained from brown calcareous shales exposed 300 feet below the Goat Spring water tank, and this horizon lies approximately 2200 feet stratigraphically below the Upper Triple Basalt.

Lower Relizian foraminifera have not been obtained from strata lying between the horizons containing upper Saucesian and upper Relizian assemblages. This may be due in large part to the scarcity of exposures and to the mantle of terrace material that covers much of the area.

The structure exhibited by the range east and southeast of the Washburn Ranch area is essentially that of an east-dipping limb of the main Caliente anticline with the northwesterly overturned Wells syncline on the flank of

[16] J. A. Cushman and Boris Laiming, Jour. Paleontol., vol. 5, no. 2, p. 88, 1931.

the anticline. In this region the northeast flank of the range is a monocline partly faulted with the nose of the Wells syncline adjacent to the northeast flank of the monocline. The strata exposed at the crest of the range north of Caliente Peak dip gently to the northeast with dips ranging from 5° to 10°. The strata at the crest are a thick series of calcareous shales with interbedded massive sandstone beds in the lower portion. Prominence of the sandstone horizons decreases upward in the section.

Southwest of Goat Spring the series of sandstones and shales is warped into a shallow syncline. The area occupied by the syncline shows a marked change from that lying immediately to the northeast. This line of topographic discontinuity can be seen on the aerial photograph (plate 3), where the undulating, poorly dissected dark-colored strata immediately southwest of the Upper Triple Basalt change abruptly, near the Goat Spring tank, into light-colored, shrub-covered strata with greater relief. The former strata are fine sandy and calcareous shales with a few thin intercalated sandstone beds, and the latter are massive sandstones with thin beds of shale. The thick shale section is probably to be correlated with the uppermost shales at the crest of the range.

The change in relief marks approximately the fault contact between the shale series and the sandstones. Approximately 600 feet southwest of the Goat Spring tank the fault contact is exposed, and here dark-colored shales butt against massive sandstone beds. The plane of the fault dips 60° southwest and the displacement appears to have occurred in such a way that the southwest side is elevated with respect to the northeast side. This apparent high-angle reverse fault has brought down a portion of the uppermost shales, which lie at the crest of the range, against the sandstones that normally underlie the shales. The minimum stratigraphic displacement is approximately 500 feet. The change in relief is apparently an expression of the difference in resistance to erosion between the shales and sandstones. Farther up in the section the down-faulted shales gradually increase in dip as the Upper Triple Basalt is approached, and here they form the southwest limb of the Wells syncline.

Northwestward from Goat Spring the faulting is less apparent and the displacement decreases, ultimately passing into a very slightly faulted and steeply overturned monocline. Southeast of Goat Spring the fault trace turns southward into the central part of the range and heads in the direction of Caliente Peak. It apparently disappears before reaching the crest of the range.

Approximately 1 mile northwest of Sulphur Spring the shallow-dipping massive sandstone beds are flexed sharply to form a monoclinal fold and are exposed as very steeply dipping beds paralleling the range. Followed along the strike, these sandstones are seen to become vertical and finally are overturned. Southeasterly the sandstones decrease, then dip, and are ultimately covered by terrace material.

Northeast of Sulphur Spring the sandstones of the monocline become less prominent and a thick shale section replaces them. These sandstones and shales decrease in dip up section and the uppermost shales decrease in dip down section from the southwest limb of the Wells syncline.

Invertebrate megafossils are relatively abundant. Both *Ostrea vespertina loeli* and *Turritella ocoyana* are found throughout the shale series. The latter form is particularly abundant in a horizon 50 feet below the Upper Triple Basalt on the northeasterly limb of the Wells syncline, locality *x*.

CORRELATIONS

From the stratigraphic position of the foraminifera and invertebrate megafossils with respect to the key basalt flows it can be demonstrated (fig. 3) that the stratigraphic position of the vertebrate remains in the red beds is restricted to strata that are later than upper Saucesian and equivalent to or slightly earlier than upper Relizian. Hence the deposits are the stratigraphic equivalent of the uppermost Temblor, as of the type section, and of a portion of the Gould shale.

AGE OF CALIENTE FAUNA

On the basis of the entire fauna and of the stage of evolution of its various constituents, the Caliente vertebrate assemblage is middle Miocene in age and is presumably intermediate between the Mascall and Sheep Creek stages. The stratigraphic correlation of this fauna with upper Temblor invertebrates and upper Relizian foraminifera places these vertebrates rather accurately in the invertebrate time scale of the California Miocene. The span of time represented by this vertebrate fauna may be measured in terms of foraminiferal stages as representing the lower portion of the upper Relizian stage and the upper portion of the lower Relizian. Thus, the deposits containing the vertebrate fauna are to be correlated with the Gould shale and upper Temblor.

Discovery of the Caliente Miocene vertebrates in a stratigraphic section containing marine invertebrate faunas necessitates a slight revision of our views regarding the position of related vertebrate assemblages in western North America.

The Merychippus zone of the North Coalinga district, according to F. D. Bode and R. M. Kleinpell, has a probable stratigraphic position immediately above the Temblor, as the latter term is employed in the type section. Its position is definitely above beds representing the uppermost zone of the upper Relizian, and within beds included in the lower Luisian stage of the marine Miocene of California. The Caliente deposits, as described in the previous section, are regarded as the equivalent of the upper Temblor of the type section and possibly of the lower portion of the upper Relizian stage. This places the Merychippus zone above the Caliente beds by the stratal unit represented by the upper Relizian.

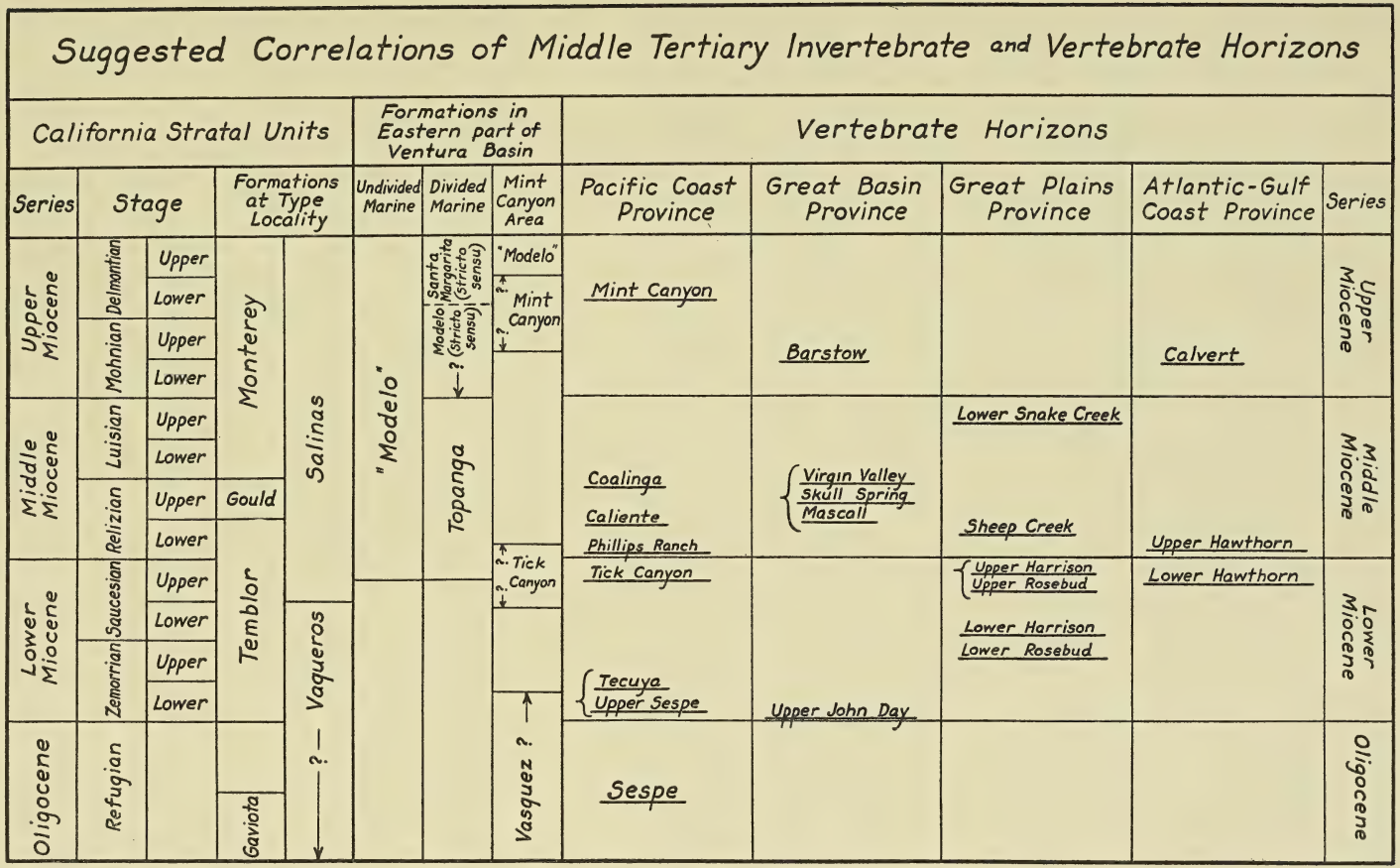


FIG. 4. Correlation chart showing time relations of middle Tertiary invertebrate and vertebrate horizons. Note position of the Caliente fauna.

The Mascall, Skull Springs, and Virgin Valley faunas are regarded by Bode as older than the Merychippus zone, and by the writer as younger than the Caliente assemblage. The Mascall and related faunas are therefore intermediate in time between the two Californian assemblages. The suggestion is therefore made that the Mascall, Skull Springs, and Virgin Valley faunal stages belong to a period of time represented in the California Coast Ranges by the Gould shale and upper Relizian stage. The Sheep Creek is certainly older than either the Mascall or Caliente and is probably the equivalent of the lower middle Miocene as this division of time is recognized in the invertebrate sequence of the California Tertiary. The correlation chart showing these relationships (fig. 4) is in part based upon observations by F. D. Bode, R. M. Kleinpell, G. G. Simpson, and R. H. Jahns.

SYSTEMATIC DESCRIPTION OF FAUNA

Equidae

Four species have been recognized among the Equidae, and these belong to the genera *Hypohippus*, *Parahippus*, and *Merychippus*. The material consists of approximately twenty-seven isolated teeth, one fragment of lower jaw with three teeth, one series of three upper molars, and several isolated limb elements. These specimens, with exception of the jaw fragment, are not particularly well preserved and do not include deciduous teeth. Despite poor preservation and small representation of teeth, it is readily seen that two species of *Merychippus* occur in the fauna, distinguished by differences in size and in crown height of teeth.

Merychippus carrizoensis, n. sp.

(Plate 4, figures 1–8*a*)

Type specimen. C.I.T. No. 2552, $M\underline{1}$, $M\underline{2}$, and $M\underline{3}$ in fragment of left maxillary. (Plate 4, figs. 1, 1*a*.)

Paratypes. C.I.T. No. 2560, $P\underline{4}$; C.I.T. No. 2558, $P\underline{3}$; C.I.T. No. 2570, $M\bar{3}$; C.I.T. No. 2575, $P\bar{4}$. (Plate 4, figs. 2–8*a*).

Specific characters. Height of crown slightly less than in *Merychippus insignis primus* (Osborn) and greater than in *M. gunteri* Simpson. Size close to that of *M. insignis primus*. Protocone attached firmly to protoconule almost immediately after wear is initiated. Teeth with very thin coat of cement. Pre-fossette exhibits two or three plications with one-quarter wear, while post-fossette is rarely plicated. Lower cheek teeth with moderately complex enamel folds; poorly cemented, but more so than are uppers. Distinct separation of metastylid on molars.

This species is represented in the collection by twelve upper teeth and ten lower teeth, all quite similar in their characters and showing very little variation.

Description. The principal characters in the teeth are the small size, short crown, attachment of protocone, and lack of any great amount of cement. The cross-sectional area is comparable to that in *M. insignis primus*. The posterior enamel border of the pre-fossette may have as many as six plications in little-worn teeth and the anterior border of the post-fossette as many as four plications, although the latter number occurs but rarely. In general

the plications are more numerous and better developed in the pre-fossette, but all plications become very faint when the tooth is worn halfway down. The pre-fossette is closed in all specimens after slight wear has taken place. A pli caballin is present in all specimens. The deposit of cement is very light externally and lingually, and appears to be restricted to areas of invagination of the enamel. The external styles are prominent and the crown is strongly curved. The curvature appears to be particularly evident in the upper third of the crown. A permanent and strong attachment of protocone and protoconule is seen shortly after wear has taken place. The metaconule-hypocone and the protoconule-protocone are distinctly loph-like in unworn teeth.

The height of the inferior cheek teeth is very similar to that of the uppers. They are a trifle smaller than those of *M. insignis primus.* The lowers are somewhat more heavily cemented than the uppers, but the amount of cement present is variable. The metaconid-metastylid column is well developed and the internal groove between the two extends well down toward the base of the crown. The metaconid-metastylid column of P$\bar{2}$, No. 2581 (plate 4, figs. 4, 4*a*), has no internal groove except at the extreme tip. The enamel pattern in these teeth is somewhat more complicated than in *M. insignis primus,* but it becomes simple in type when the tooth is worn more than one-third of its height.

Comparisons. *Merychippus carrizoensis* is close to the type of *M. brevidontus* Bode in size of tooth crown, but the teeth of the former are shorter-crowned. The most striking differences are presented by the complexity of the enamel pattern, the heavy cementation, and the detached protocone of *M. brevidontus.* The latter species is more advanced and certainly specifically different from the Caliente form. The lower teeth of the Coalinga species are somewhat higher-crowned and possess a more complicated enamel pattern than do those of *M. carrizoensis.* The metaconid-metastylid column is better developed in the former and the internal gutter more clearly defined. Moreover, protoconid and hypoconid exhibit a small fold which projects internally from their inner walls, a character not present in specimens from the Caliente region.

Merychippus californicus Merriam is not closely related to the Caliente species. In the former the teeth are much larger and higher-crowned, and upper cheek teeth have discrete protocones. The deposit of cement is also very much heavier in *M. californicus.*

The teeth of *M. relictus* are slightly higher-crowned and have more complicated fossette borders and heavier cement than do those of the Caliente species. In the upper cheek teeth of Cope's species the protocone is an isolated cusp and remains so even in teeth that are very well worn. *Merychippus carrizoensis* resembles *M. relictus* in cross-sectional area of the crowns of the cheek teeth.

Merychippus vellicans and *M. socius* of the Navasota, Texas, Miocene [17] are very similar in stage of evolution to *M. carrizoensis.* The former species appears to be somewhat higher-crowned and more heavily cemented, and has more complicated fossette borders. The protocone does not become strongly attached to the protoconule until the crown is moderately worn. As in *M. gunteri* and the Caliente species, the metastylid-metaconid are but very slightly separated in P$\bar{2}$, even though well developed in the other lower teeth. *Merychippus socius* is lower-crowned than *M. vellicans* and approaches the Caliente species very closely. The protocone of this species

[17] O. P. Hay, Proc. Biol. Soc. Washington, vol. 37, p. 7, 1924.

also does not unite strongly with the protoconule until moderately well worn. This character in both Texas forms distinguishes them from *M. carrizoensis.*

In the teeth of *M. isonesus* Cope the crowns are much higher, with isolated protocone and heavier cement. The lowers of this species are similar in pattern to those of the Caliente form, but the latter are smaller and shorter-crowned.

Among species recorded from Tertiary deposits of eastern North America, *M. insignis primus* (Osborn) of the Sheep Creek middle Miocene [18] is most closely related to the small Caliente *Merychippus.* Comparison with topotypic material in the American Museum collections suggests that the Californian material represents a species of *Merychippus* distinguished from *M. insignis primus* only in details. The height of crown of unworn specimens from the Caliente Miocene is somewhat less than in teeth of *M. i. primus.* A thinner deposit of cement is present in the Caliente specimens, but some of this material may have been worn away in the process of transportation and burial. Both types show practically the same degree of complexity of the fossette borders and have the pli caballin present in upper cheek teeth. The union of protocone and protoconule takes place at almost exactly the same place in the height of the crown, and the isthmus is of comparable width in these species. Likewise, the cross-sectional areas of the crowns of the cheek teeth at similar stages of wear are much alike. The lingual border of protocone and hypocone in *M. insignis primus* is flattened somewhat, but this difference between the Sheep Creek and Caliente species is not striking.

The characters of the lower teeth in the two species are also similar. Crown height and amount of cement are less in Caliente specimens, but the enamel patterns of the two forms are strictly comparable. The stage of development of the metaconid-metastylid column is almost identical. The lower cheek teeth of *M. carrizoensis* appear to be smaller in over-all size. The difference in size of the premolars and molars in specimens of *M. insignis primus* is observed also in teeth of *M. carrizoensis.* Thus, the latter species appears to be slightly less advanced than *M. insignis primus,* although individual specimens are sometimes difficult to distinguish from the latter except for the presence of less cement.

Merychippus gunteri Simpson [19] of the Hawthorn middle Miocene is also close to the Caliente species. Simpson suggests that *M. gunteri* is a member of the *Merychippus insignis* group, and that the Florida species is somewhat more advanced than *M. insignis primus.*[20] The latter statement is difficult to understand in view of the fact that *M. gunteri* is described as having shorter-crowned teeth that are smaller in size, and has a more complex enamel pattern than does *M. insignis primus.*

From the description and illustrations it appears that the teeth of *M. gunteri* have slightly shorter crowns than those of the Caliente form, although they are close in crown size. The complexity of fossette borders and early union of protocone and protoconule are further characters in common. A simple pli caballin is present in both forms, and judging from the illustrations, the cement on the teeth of the Florida species appears to be almost as slight as that on teeth of *M. carrizoensis.* The lower teeth are similar in their enamel patterns. The over-all dimensions of the lower teeth of *M. gunteri* appear to be greater than in the Caliente form. One

[18] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, art. 2, p. 162, 1924.
[19] G. G. Simpson, Bull. Amer. Mus. Nat. Hist., vol. 59, art. 3, p. 163, 1930.
[20] *Ibid.*, p. 165, 1930.

character seen in both the California and the Florida species is the feeble separation of the metastylid in P$\bar{2}$, although it is distinct in the remaining teeth.

The Hawthorn species is probably more primitive than *M. carrizoensis*, and may be comparable to the primitive merychippine type from the Phillips Ranch horizon of California. As a matter of fact this similarity between lower teeth from the Florida Miocene and those from Phillips Ranch was noted by Merriam.[21]

Merychippus carrizoensis possesses characters which appear to place it between *M. gunteri* and *M. insignis primus*. The California species is certainly more closely related to these forms than to *M. brevidontus* or *M. californicus*.

Comparative measurements (in millimeters)

1. *Merychippus carrizoensis* n. sp.
2. *Merychippus gunteri* Simpson.
3. *Merychippus insignis primus* (Osborn).
4. *Merychippus brevidontus* Bode.
5. *Merychippus californicus* Merriam.

Superior dentition	1 C.I.T.	2 F.S.G.S. No. V-4959	3 A.M.N.H. No. 1893	4 C.I.T.	5 C.I.T. No. 1405
P$\underline{2}$, anteroposterior diameter	(2553) 21.0	....	20.0	(1421) 22.2	21.4
P$\underline{2}$, transverse diameter	16.5	....	16.8	18.7	18.6
P$\underline{3}$, anteroposterior diameter	(2558) 16.8	....	16.0	(1414) 19.8	21.7
P$\underline{3}$, transverse diameter	19.5	....	19.1	22.0	21.0
P$\underline{4}$, anteroposterior diameter	(2560) 16.9	....	15.5	(1413) 18.0	21.0
P$\underline{4}$, transverse diameter	18.8	....	19.4	19.7	21.4
M$\underline{1}$, anteroposterior diameter	(2552) 16.6	....	15.0	(1409) 18.0	18.8
P$\underline{4}$, transverse diameter	18.0	....	19.0	19.0	20.0
M$\underline{2}$, anteroposterior diameter	(2552) 16.0	14.5	15.8	(1408) 18.0	19.0
M$\underline{2}$, transverse diameter	19.5	20.0	19.2	21.0	20.0
M$\underline{3}$, anteroposterior diameter	(2552) 14.3	14.5	16.0	(1423) 18.5	19.0

Inferior dentition	C.I.T.	F.S.G.S. No. V-4962	A.M.N.H. No. 1893	C.I.T.	C.I.T. No. 488
P$\bar{2}$, anteroposterior diameter	(2581)	....	15.3	.....	18.7
P$\bar{2}$, transverse diameter	9.1	....	9.6	.....	9.7
P$\bar{3}$, anteroposterior diameter	(2573) 15.6	17.0	15.5	.....	18.7
P$\bar{3}$, transverse diameter	10.1	12.0	11.3	.....	10.8
P$\bar{4}$, anteroposterior diameter	(2577) 15.7	17.0	15.6	(1491) 19.2	19.0
P$\bar{4}$, transverse diameter	10.3	12.5	11.2	11.5	11.0
M$\bar{1}$, anteroposterior diameter	(2578) 15.0	16.0	14.5	(1426) 18.0	16.8
M$\bar{1}$, transverse diameter	9.7	11.5	10.3	10.7	9.0
M$\bar{2}$, anteroposterior diameter	(2576) 14.4	17.0	15.0	(1430) 18.6	18.5
M$\bar{2}$, transverse diameter	8.9	11.0	9.7	10.0	8.7
M$\bar{3}$, anteroposterior diameter	(2570) 16.0	....	19.0	.....	20.6
M$\bar{3}$, transverse diameter	7.2	....	8.1	.....	7.8

Merychippus stevensi, n. sp.

(Plate 4, figure 9; plate 5, figures 2–6*a*)

Type specimen. C.I.T. No. 2582, M$\underline{1}$ or M$\underline{2}$. (Plate 5, figs. 6, 6*a*.)

Paratypes. C.I.T. No. 2562, Dp$\underline{3}$, slightly worn; C.I.T. No. 2555, M$\underline{1}$, well worn; C.I.T. No. 2571, M$\underline{3}$; and C.I.T. No. 2572, lower cheek tooth. (Plate 5, figs. 2–5*a*.)

[21] H. F. Osborn, Mem. Amer. Mus. Nat. Hist., n. s., vol. 2, p. 108, 1918.

Specific characters. One-third larger, with cheek teeth higher-crowned than in *M. carrizoensis.* (Compare plate 4, figs. 1 and 9.) Height and size of crown comparable to that in *M. isonesus.* Fossette borders of upper cheek teeth less complicated than in *M. californicus.* Protocone attached firmly to protoconule, this union occurring immediately after wear begins. The writer takes pleasure in naming this species for John B. Stevens, geologist of the Associated Oil Company of California.

Merychippus stevensi is represented by eight upper teeth, two fragmentary lowers, and an ungual phalanx of the median digit. Some variation in characters is exhibited by the teeth, but all specimens are distinct from those referred to *M. carrizoensis.*

Description. The specimens referred to *M. stevensi* (plate 5, figs. 2–6*a*) are considerably larger and higher-crowned than those of the small *Merychippus* in the fauna. As in *M. carrizoensis,* the protocone is attached, and in this character the teeth differ from those of *M. isonesus* and *M. californicus.* The dimensions of the tooth crown are on the average almost exactly those of *M. isonesus.* The enamel pattern of the occlusal surface shows slight complication. Usually three to five plications of the fossette border are seen in half-worn teeth. The pli caballin is simple. The amount of cement present is variable, but it is quite heavily deposited on well-preserved teeth.

The inferior cheek teeth are represented only by two fragments. A broken $M\overline{3}$ (plate 5, figs. 5, 5*a*) appears to be much higher-crowned and larger than the lowers of *M. carrizoensis.* The second fragment has a moderately complex enamel pattern, similar to that which is found in *M. californicus.*

One specimen, probably a milk tooth of this Caliente form, C.I.T. No. 2562 (plate 5, figs. 4, 4*a*), is similar to milk premolars of *M. isonesus.* No. 2562 is hypsodont with protocone and hypocone tending to form pillars as in deciduous teeth of *M. californicus.*

In the cheek teeth of *M. stevensi* the crowns are from a quarter to a fifth shorter than in *M. californicus.* The five species resemble each other in the areas of their occlusal surfaces and in the dimensions of these teeth. Cement forms a much thicker substance in teeth of the former, although, as Bode [22] has pointed out, this character is highly variable and of doubtful diagnostic value in many cases. The fossettes in upper cheek teeth of *M. stevensi* show only slight complications of their borders; and the pre-fossettes appear to be closed in all specimens. The latter feature contrasts with the condition found in *M. californicus,* for in the species from the Merychippus zone 70 per cent of the premolars have the pre-fossette open until the crowns are half worn. The Caliente species differs markedly from *M. californicus* in very early attachment of the protocone. *Merychippus stevensi* is certainly distinct from and less advanced than *M. californicus.*

Merychippus francisi Hay [23] is distinguished from *M. stevensi* by its shorter crown and by the weak union of the protocone to the protoconule. The lower teeth appear to have more complicated enamel patterns. The paucity of illustrated and described material of this species prohibits close comparison with the Caliente form. *Merychippus francisi* is probably slightly less advanced than *M. stevensi* and is certainly distinct specifically, even though closely related in time and in its evolutionary characters.

[22] F. D. Bode, Carnegie Inst. Wash. Pub. No. 453, paper V, p. 53, 1934.

[23] O. P. Hay, *op. cit.,* p. 9, 1924.

Merychippus insignis primus has distinctly lower-crowned teeth and is a smaller type, although in the relation of protocone to protoconule it shows considerable resemblance to *M. stevensi*.

On the basis of the comparisons which have been made, *Merychippus stevensi* appears to be close to *M. isonesus* in stage of evolution and is less advanced than *M. californicus*. No described species is strictly comparable to the Caliente form and hence, although the specimens are few in number, it seems desirable to recognize it as a distinct type.

Height of crown of cheek teeth in merychippine species

(Measurements of unworn upper teeth in millimeters)

Horizon	Species	Maximum	Mean	Minimum
Sheep Creek*...	*Merychippus insignis primus* (Osborn).....	22	.....	16
Caliente.....	*Merychippus carrizoensis*, n. sp.....	23	.....	16
	Merychippus stevensi, n. sp.....	33‡	.....	28‡
Mascall†.....	*Merychippus isonesus* Cope.....	34	29	26
Coalinga†.....	*Merychippus californicus* Merriam.....	42	34	29
Barstow†.....	*Merychippus sumani* Merriam or *Merychippus intermontanus* Merriam.....	46	36	32

* Measurements of unworn or slightly worn topotypic specimens.
† Measurements after Bode, 1934.
‡ Estimated.

Parahippus (?) sp.

(Plate 5, figures 1–1*b*)

With the type of *Merychippus stevensi* at locality 322 is found a fragmentary left ramus of a small anchitheriine horse, C.I.T. No. 2586, which retains $P\bar{4}$, $M\bar{1}$, and $M\bar{2}$. The teeth are moderately worn and well preserved.

The jaw is deep, much more so than that of *Archaeohippus mourningi*. In this respect the specimen shows more resemblance to *Parahippus*. Cement appears to be completely lacking, but a thin deposit in the lingual valleys may represent a slight amount of this substance. F. D. Bode [24] cites the following characters as distinguishing *Archaeohippus* from *Parahippus*: "(1) Complete absence of a crochet, (2) constant thin and straight alignment of protoloph and metaloph, (3) precocious development of crown-height relative to small size of tooth, (4) complete absence of cement, and (5) peculiar and characteristic development of the preorbital fossae as shown in *A. ultimus* and in *A. penultimus*." One additional character mentioned by Bode may be of value, namely, "the maximum transverse diameter for the cheek-tooth series occurs in $P\frac{4}{4}$, an advance beyond the position in which this measurement is found in typical members of the anchitheriine group." [25] It is unfortunate that the Caliente form is represented only by lower teeth. Under these circumstances the characters useful in determining the relationships of the Caliente species are limited to the presence or absence of cement, position of maximum transverse tooth diameter in jaw, and general size and proportions of jaw and teeth.

The apparent absence of cement in No. 2586 suggests a relationship with *Archaeohippus*, but the robustness and depth of the jaw when compared

[24] F. D. Bode, Carnegie Inst. Wash. Pub. No. 440, paper V, p. 57, 1933.
[25] *Ibid.*, 1933.

with that of *Archaeohippus mourningi* suggests a larger, heavier *Parahippus*-like form. Lack of cement seems to characterize several species of *Parahippus*, as for example *P. agrestis* and *P. pristinus*. Some specimens of *P. leonensis* also show this character. If correctly referred to *Parahippus*, the species from Caliente Mountain is certainly smaller than most species listed by Schlaikjer [26] in his discussion of the genus. This species appears to be smaller than *P. tyleri* and *P. leonensis*, and is probably larger than *P. pristinus*. The Caliente species may represent a dwarf form or the survival of a primitive type.

$P\overline{4}$ is larger and more robust than the molars. All teeth possess faint external cinguli, and internal cinguli are limited to the anterior and posterior faces of each tooth. The metaconid and metastylid are separated slightly at the top of the crown, but the separation disappears in the lower half of the tooth. The entoconid and entostylid appear to be well developed.

Measurements (in millimeters)

	Parahippus (?) sp. C.I.T. No. 2586
$P\overline{4}$, anteroposterior diameter	14.0
$P\overline{4}$, transverse diameter	10.8
$M\overline{1}$, anteroposterior diameter	13.0
$M\overline{1}$, transverse diameter	9.2
$M\overline{2}$, anteroposterior diameter	13.0
$M\overline{2}$, transverse diameter	9.0

Hypohippus (?) sp.

The greater portion of a tibia with an articulated astragalus, C.I.T. No. 2551, appears to represent this anchitheriine genus. These elements were found at locality 323, approximately 50 feet stratigraphically above a horizon containing *Merychippus* and *Parahippus*. The tibia lacks the proximal end including the cnemial crest, although the rest of the specimen is well preserved, with the astragalus in articulation. The elements belong to a very large, heavy-limbed horse. The only figured or measured tibia of *Hypohippus* available for comparison is that of *Hypohippus* (*Drymohippus*) *nevadensis* [27] from the Cedar Mountain beds of Nevada. No. 2551 is very similar in its proportions to the latter but is smaller in some measurements.

Measurements (in millimeters)

	Hypohippus (?) sp. C.I.T. No. 2551
Tibia:	
Length (approximate)	400
Greatest transverse diameter of distal end	73
Astragalus:	
Greatest transverse diameter	57
Greatest height of articular surface with the tibia	60

Rhinocerotidae

Rhinocerotid sp.

Presence of a rhinocerotid in the fauna is indicated by several fragments of teeth, C.I.T. No. 2547. The available material suggests a type with relatively small, short-crowned teeth.

[26] E. M. Schlaikjer, Bull. Mus. Comp. Zool., Harvard, vol. 80, no. 5, p. 271, 1937.
[27] J. C. Merriam, Univ. Calif. Publ., Bull. Dept. Geol., vol. 9, no. 13, p. 422, 1916.

MERYCOIDODONTIDAE

Merychyus calimontanus, n. sp.

(Plate 6, figures 1–6*a*)

Type specimen. C.I.T. No. 2543, palate with dentition but lacking the right upper incisor teeth. Some limb fragments are associated with palate. (Plate 6, figs. 1–5*a*.)

Referred specimens. C.I.T. No. 2545, fragmentary left maxillary with $P\underline{4}$, and $M\underline{1}$ to $M\underline{3}$ inclusive. C.I.T. No. 2544, a fragmentary left ramus with $P\overline{4}$, and $M\overline{1}$ to $M\overline{3}$ inclusive. (Plate 6, figs. 6, 6*a*.) C.I.T. No. 2546, palate with deciduous teeth and $P\underline{4}$–$M\underline{3}$.

Specific characters. Size larger than that of *Merychyus elegans* and very close to that of *M. harrisonensis*. The anterior premolars are less reduced and crowded than in *M. elegans*. Posterior transverse spur of $P\underline{3}$, projecting inward from principal cusp, not connected with inner border of crown. Premolars slanting posteriorly more than in *M. harrisonensis* and less than in *M. elegans*.

Description and comparison. The author is indebted to Dr. Chester Stock for his notes on the types of *M. elegans* and *M. arenarum*.

The Caliente species is slightly larger than *M. elegans*, U.S.N.M. No. 120. The basic patterns of the premolars in the two species are very similar, but significant differences are present in $P\underline{3}$ and $P\underline{2}$. $P\underline{2}$ has a shorter anterior oblique spur, and the middle transverse spur is directed posteriorly, rather than inward and slightly forward as in No. 120.

The occlusal surface of $P\underline{3}$ in No. 120 is slightly broader for its length than in *M. calimontanus*. The most important character appears to be shown by the posterior transverse inner spur of the principal cusp in $P\underline{3}$. In *M. elegans* this spur meets the inner border of the tooth and forms two basins on the internal side. In *M. calimontanus* the spur does not reach the inner border of the crown, and the anterior basin is not closed. The spur does not seem to connect with the inner border until the tooth is very well worn. The premolars of *M. elegans* are smaller with respect to the molars than are those of *M. calimontanus*. The premolar-molar index of *M. elegans* is 0.71, and that of *M. calimontanus* is 0.76.

Merychyus arenarum, A.M.N.H. No. 8146 from the upper Harrison, is very similar in size to *M. calimontanus*. The premolars and molars of this specimen have greater length than those of *M. arenarum*, although their width is very nearly the same. The premolar indices are 0.76 and 0.72 respectively.

$P\underline{4}$ of *M. calimontanus* lacks the well-developed internal cingulum of No. 8146. $P\underline{4}$ and $P\underline{3}$ are not so long-crowned as are the comparable teeth in the Californian species.

As in *M. elegans*, the posterior internal oblique spur from the principal cusp extends to the inner border of the crown. This type of spur appears to occur in other species of *Merychyus*, in so far as this can be determined from illustrations in Thorpe's monograph.[28] The specimens from Caliente Mountain thus differ from these species in the absence of a connection between this spur and the internal wall of the crown of $P\underline{3}$.

The paratypic lower dentition, C.I.T. No. 2544 (plate 6, figs. 6, 6*a*), possesses the typical $P\overline{4}$ of *Merychyus*, as figured by Loomis.[29] $P\overline{4}$ in this specimen is almost exactly like that in the type of the genus. The lower

[28] M. R. Thorpe, Mem. Peabody Mus. Nat. Hist., vol. 3, part 4, 1937.

[29] F. B. Loomis, Bull. Amer. Mus. Nat. Hist., vol. 51, art. 1, 1924.

molars tend to become square in cross section, in which respect they differ from those of *M. elegans* and *M. arenarum.*

Merychyus harrisonensis of the lower Harrison is slightly larger in over-all length of dentition, but is close in size of individual teeth. The premolar-molar index of the former is 0.77, and the premolars appear to be slightly smaller although less crowded and less reduced anteriorly than those of *M. calimontanus.* Thorpe [30] considers *M. harrisonensis* the most primitive form of the genus *Merychyus. Merychyus calimontanus* has more advanced features than the lower Harrison form, and less advanced features than *M. elegans* of the upper Miocene (?). The stage of evolution of the Californian species suggests a middle Miocene age.

Associated with the type palate, No. 2543, are fragments of both hind limbs. The distal end of a left femur, the proximal ends of the left and right tibiae, both astragali and calcanei, and several metatarsals and phalanges are preserved. The metatarsals are quite long and slender, and the shaft of the tibia is narrow and elongate. The proportions of the hind limbs of this specimen are strictly comparable to those of the smaller *M. elegans minimus.* Comparison with the proportions of *Promerycochoerus vantasselensis* demonstrates the differences between the long-limbed, light forms and the short-limbed, heavy types. In the latter genus and species the calcaneum is longer than metatarsal IV, while in the former metatarsal IV is one-third longer than the calcaneum. Similarly, the metatarsals of *P. vantasselensis* are one-third broader than those of *M. calimontanus,* although very similar in length.

A fragmentary palate of *M. calimontanus,* No. 2646, bearing deciduous premolars, occurred at the same stratigraphic level but several tens of feet east of the occurrence of the type adult palate. Dp3, Dp4, and M1 are preserved on both sides. Dp3 is short-crowned with moderately prominent external styles. In its front portion the tooth has anterior and antero-internal basins which are flattened and compressed as in the permanent premolars, but the posterior portion of the tooth appears to have the simple crescent and pillar of a molar. Dp4 is short-crowned with prominent external styles. It is molariform, with double crescents and pillars. M1 is longer-crowned than the deciduous teeth and has very strong external styles.

Comparative measurements (in millimeters)

1. *Merychyus arenarum* Cope.
2. *Merychyus elegans* Leidy.
3. *Merychyus elegans* Leidy.
4. *Merychyus calimontanus,* n. sp.
5. *Merychyus calimontanus,* n. sp.
6. *Merychyus harrisonensis* Peterson.*

Superior dentition	1 A.M.N.H. No. 8146	2 A.M.N.H. No. 120	3 A.M.N.H. No. 121	4 C.I.T. No. 2543	5 C.I.T. No. 2545	6 C.M. No. 1341
Length, anterior end of C to posterior end of M3		86.0	88.7	92.2	.....	95.0
Length, anterior end of P1 to posterior end of M3		76.4	77.4	81.9	.....	82.0
Length, anterior end of P3 to posterior end of M3	63.1	.....	.....	65.0	.....	.....
C, transverse width		7.7	7.2	8.2	.....	8.0
P1, greatest oblique length		6.9	7.6	8.6	.....	8.0
P1, width normal to length		4.3	4.6	5.2	.....	4.0

[30] M. R. Thorpe, *op. cit.,* 1937.

Comparative measurements (in millimeters)—continued

Superior dentition—*continued*	1 A.M.N.H. No. 8146	2 A.M.N.H. No. 120	3 A.M.N.H. No. 121	4 C.I.T. No. 2543	5 C.I.T. No. 2545	6 C.M. No. 1341
P2, length along outer side	.....	8.2	8.4	8.6	.....	10.0
P2, greatest width	.....	7.2	6.4	7.3	.....	7.0
P3, length along outer side	9.3	8.9	8.7	10.2	.....	9.5
P3, greatest width	9.3	8.7	7.8	9.2	.....	8.0
P4, length along outer side	8.8	8.9	8.1	9.0	9.0	8.6
P4, greatest width	12.0	10.7	9.5	11.8	11.9	11.5
M1, length along outer side	12.3	12.9	11.7	12.6	13.7†	12.0
M1, greatest width	13.3	13.8	12.5	13.6	13.0	13.5
M2, length along outer side	15.6	15.2†	16.0	17.5	16.9†	15.0
M2, greatest width	14.9	14.8	15.1	15.2	15.8†	15.0
M3, length along outer side	19.0	20.5	22.2	19.2	20.5	20.0
M3, greatest width	15.6	17.3	15.5	16.6	15.8	16.1

Inferior dentition				C.I.T. No. 2544
Length, anterior end of P4 to posterior end of M3	60.7	.....	.....	61.0
P4, length along inner side	12.4	10.8	10.7	11.4
P4, greatest width	9.5	7.8	7.0	8.3
M1, length along inner side	12.2	11.8	11.1	11.4
M1, greatest width	9.5	8.7	8.7	9.5
M2, length along inner side	14.3	14.5	14.3	14.4
M2, greatest width	10.9	9.9	10.7	11.1
M3, length along inner side	23.0	.....	24.1	25.8
M3, greatest width	10.3	.....	10.0	10.6†

* Measurements from Thorpe, 1937.
† Approximate.

Ticholeptus (?) sp.

(Plate 7, figure 1)

A badly crushed skull and lower jaws of this merycoidodont, C.I.T. No. 2550, was found at locality 315 in association with remains of a merychippine horse. Although lacking only the anterior portion of skull and jaws and the extreme posterior end of the skull, this specimen has suffered so badly from crushing that exact measurements and comparisons cannot be made. A calcareous infiltration of the specimen has likewise obscured somewhat the character of the dentition. Hence, only a tentative generic determination can be recorded.

The skull is long and deep, its length falling within that of known species of *Ticholeptus* and well above that of *Merychyus*. The species of the *Merycochoerus* line are, on the other hand, considerably larger and more robust. The nasals appear to be long. The brain case is narrow, relatively high, and short. The orbits are small and nearly circular in outline. The zygomatic processes of the jugal appear to be thin, and in all probability the zygomatic arches were slender. A small facial vacuity lies immediately anterior to the orbits. A larger depression occurs farther forward in the left maxillary, but this is probably the result of crushing.

In the lower jaw the coronoid process is short and thin, and the condyle is robust. The angle is worn away, but the jaw is essentially complete in depth below M3.

The superior dentition is badly crushed except for M3. The anterior premolars are absent and P3 and P4 are only partly preserved. The length of the superior molar series lies between that of *Ticholeptus brachymelis*

Douglass and that of *Ticholeptus rusticus* (Leidy).[31] The diameter of $M\underline{3}$ is greater in No. 2550 than in the former species, and smaller than that of the latter.

The dimensions of the lower molars are quite close to those of *T. rusticus*.

The characters of the Caliente specimen are not those of any described middle Tertiary oreodont, although it must be conceded that the structural features are so poorly exhibited as to obviate the possibility of recognizing this form as a new species. The probable presence of slender zygomatic arches, the long, high, and narrow skull, and the size suggest that the specimen belongs to the genus *Ticholeptus*. However, without the characters of the premolars, this determination is still open to question. The proportions of the specimen appear to be between those of *T. brachymelis* and those of *T. rusticus*.

Comparative measurements (in millimeters)

Skull	*Ticholeptus* (?) sp. C.I.T. No. 2550	*T. brachymelis** A.M.N.H. No. 9731	*T. rusticus* A.M.N.H. No. 19–104
Maximum length	265.0†	257.0	270.0
Postorbital constriction, diameter	40.0†	40.0	52.5
Orbit, anteroposterior diameter	28.0†	28.0	40.0
Orbit, vertical diameter	29.0†	30.0†	42.0
Depth of ramus below $M\underline{3}$	46.0†	45.0	52.5
Dentition			
Superior molar series	64.0†	60.0	65.4
$M\underline{3}$, anteroposterior diameter	26.0	25.5	29.5
$M\underline{3}$, transverse diameter	18.0†	23.5	22.1
Inferior molar series	66.0†	64.0	65.4
$M\underline{1}$, anteroposterior diameter	14.0†	16.0	14.7
$M\underline{1}$; transverse diameter	13.0†	....	12.6
$M\underline{2}$, anteroposterior diameter	21.5	18.0	21.1
$M\underline{2}$, transverse diameter	15.5	....	15.2
$M\underline{3}$, anteroposterior diameter	32.5	29.0	32.6
$M\underline{3}$, transverse diameter	15.0†	....	14.7

* Measurements from Thorpe, 1937.
† Approximate.

Merycoidodont sp. *a*

(Plate 7, figures 2, 2*a*)

A single lower second molar in a jaw fragment, C.I.T. No. 2548, has merycoidodont characters. The crown is moderately well worn and tends toward hypsodonty. It is larger than comparable teeth of *Ticholeptus* described by Thorpe.[32] The size and proportions of the tooth lie within the range of teeth of *Merycochoerus*, and are close to those of $M\underline{2}$ of *Merycochoerus buwaldi* Merriam.

Measurements (in millimeters)

$M\underline{2}$, anteroposterior diameter	23.5
$M\underline{2}$, transverse diameter	17.2

[31] M. R. Thorpe, *op. cit.*, p. 287, 1937.
[32] *Ibid.*, 1937.

Merycoidodont sp. *b*

(Plate 7, figures 3, 3*a*)

A single lower left M$\bar{1}$, C.I.T. No. 2587, several incomplete limb elements, a symphyseal portion of a mandible, and several broken caniniform teeth are referred to this form. The material is from locality 325, and is stratigraphically the lowest vertebrate occurrence. M$\bar{1}$ is very similar to the comparable tooth in specimens of *Merychyus calimontanus*. Its stratigraphic position is approximately 2400 feet below that of *M. calimontanus*.

Camelidae

Camelid (?), gen. and sp. indet.

Two small astragali, C.I.T. No. 2588, are closely similar in size and proportions to camelid astragali in the collections from the Merychippus zone. The latter have been referred tentatively to *Miolabis*.

Cervidae

Dromomeryx (?) sp.

(Plate 7, figures 4, 4*a*)

A portion of a lower molar, C.I.T. No. 2549, resembles very closely M$\bar{2}$ of *Dromomeryx borealis*.[33] The tooth is low-crowned, with rugose enamel on the external pillars. The forward internal crescent overlaps the anterior portion of the posterior crescent. A cuspule, oval in cross section, lies between the two external crescents. The anterior crescent is well worn and shows only a trace of the "paleomeryx-fold."

An incomplete astragalus, C.I.T. No. 2568, from locality 315 may be referable to this genus. Comparisons with merycoidodont and camelid astragali reveal several differences. This specimen tends to be wider transversely and lacks the peculiar twist seen in the upper ball of merycoidodont astragali. Differences from camelid astragali are less apparent, although in its robustness the specimen contrasts with the slender, elongate astragali of middle Miocene camelids.

Antilocapridae

Antilocaprid sp.

(Plate 7, figures 5–6*a*)

This form is known by fragments of several lower jaws and isolated superior molar teeth. The material represents the first vertebrate fossil collected in the Caliente area, and was found by John B. Stevens in red sandstone approximately 250 feet above the Main Basalt at Padrones Spring, locality 170. It also represents the only vertebrate fossil material obtained thus far from beds above the Main Basalt.

C.I.T. No. 642, an anterior portion of a left mandible with the roots of P$\bar{2}$–P$\bar{4}$ preserved, and C.I.T. No. 2686, a posterior portion of a left ramus containing the posterior half of P$\bar{4}$ and M$\bar{1}$–M$\bar{3}$, exhibit the characters of this form to best advantage. In the collections of the University of California are additional fragments from this same locality, U.C. No. 28300.

[33] E. Douglass, Ann. Carnegie Mus., vol. 4, p. 468, 1909.

Description and comparison. The anterior portion of the jaw, No. 642 (plate 7, figs. 5, 5*a*), is characterized by a very short post-symphyseal diastema and relatively unreduced premolars. The length of the diastema is most nearly comparable to that in a species of Frick's subgenus "*Paracosoryx*," [34] represented by *Merycodus sabluonis* Matthew and Cook. Also in this latter species the premolars are relatively unreduced with respect to the molar series. The crowns of the premolars are missing from the Caliente specimen, but the lengths of the roots across the alveoli can be determined. The posterior mental foramen lies below the anterior root of $P\underline{2}$. The jaw is relatively robust below the premolars, lacking the slimness and great length of diastema of *Merycodus* cf. *cerroensis* (Frick) [35] of the Avawatz Pliocene. The premolars of this latter species are very much more reduced than in the Caliente form.

C.I.T. No. 2686 (plate 7, figs. 6, 6*a*), the posterior portion of a jaw, is relatively robust and deep. The posterior portion of $P\underline{4}$ is present and appears to be rather high-crowned. The crown height of an unworn $M\underline{3}$ is almost exactly equal to that of *Ilingoceros alexandrae* Merriam, although the latter is much larger and from a later stage in the Tertiary of western North America. The molar teeth of No. 2686 are much higher-crowned than in *M.* cf. *cerroensis* (Frick), although $M\underline{1}$–$M\underline{3}$ has the same length in both forms. This rear portion of the jaw is also more robust and deeper. *Merycodus sabluonis* is slightly smaller and has similar proportions, but its molars are much lower-crowned.

In summary it may be stated that the Caliente form is characterized by a short post-symphyseal diastema, relatively unreduced premolars, very high-crowned molars, and a deep, rather robust jaw.

Of the many forms illustrated by Frick there appears to be none that possesses these characteristics, and in the absence of horn core and skull material it is impossible to determine the genus. It seems possible, in view of the extreme hypsodonty of the molars, that this form might be a middle Miocene representative of the antilocaprid group that gave rise to *Ilingoceros*, *Plioceros*, and *Texoceros* in the Pliocene.

Comparative measurements (in millimeters)

1. Antilocaprid sp. Caliente.
2. *Merycodus sabluonis* (Matthew and Cook).*
3. *Merycodus* cf. *cerroensis* (Frick).
4. *Ilingoceros alexandrae* Merriam.*

	1 C.I.T. No. 642	2 A.M.N.H. No. 20530	3 C.I.T. No. 1997	4 F.A.M. No. 32207
Length of diastema from posterior border of anterior mental foramen to anterior border of $P\underline{2}$	18.7	17.0	30.5	31.0
Length, $P\underline{2}$–$P\underline{4}$ on alveoli	20.4	17.5	15.4	25.5
Depth of jaw below $P\underline{2}$	13.2	....	11.0	....
Length of premolars on alveoli:				
$P\underline{2}$, length	5.0	....	3.6	7.0
$P\underline{3}$, length	6.1	6.3	5.3	9.1
$P\underline{4}$, length	8.8	7.5	6.4	9.7

* Measurements after Frick.

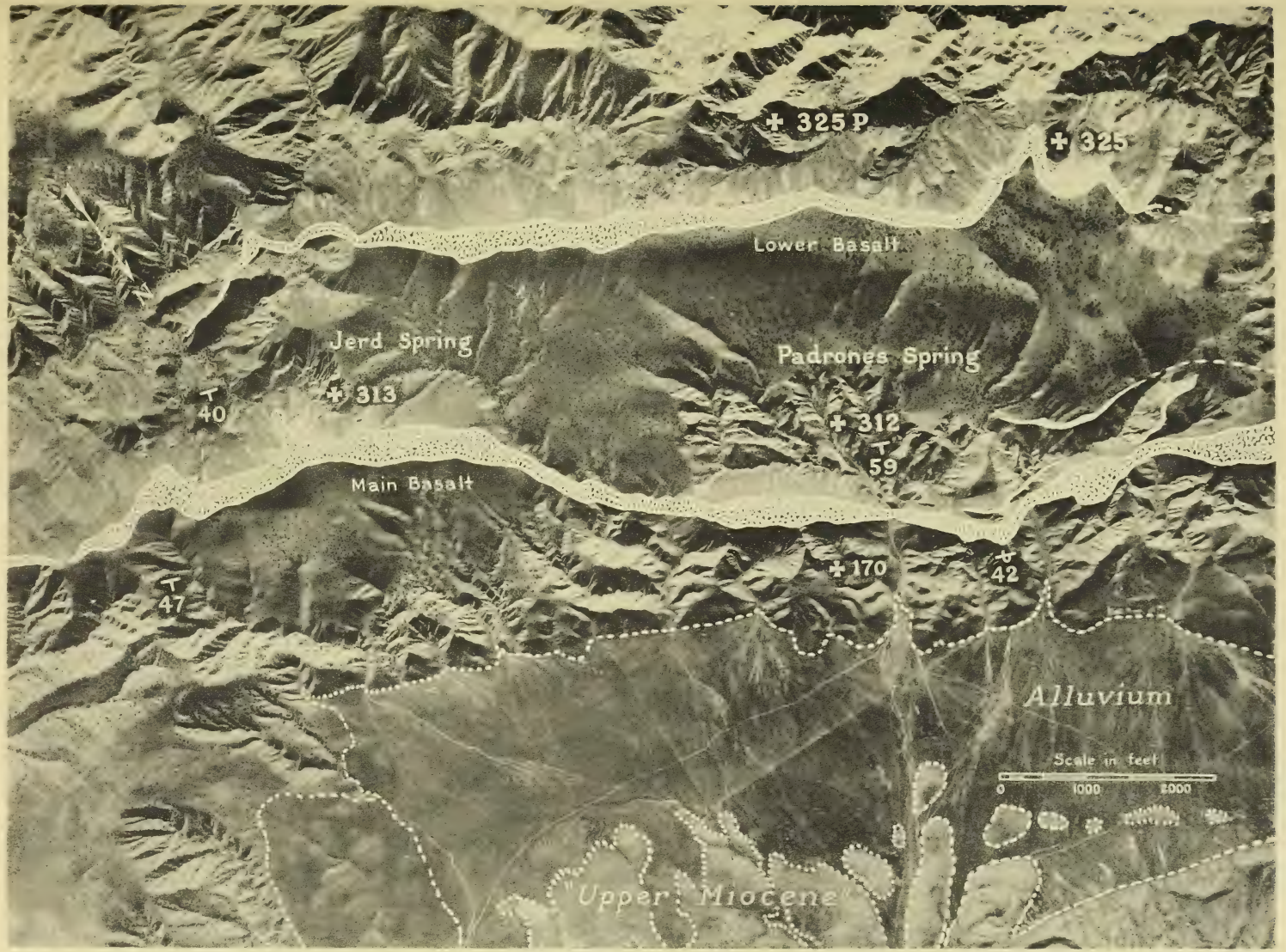
[34] C. Frick, Bull. Amer. Mus. Nat. Hist., vol. 69, p. 378, 1937.

[35] P. C. Henshaw, Carnegie Inst. Wash. Pub. No. 514, paper I, p. 23, 1939.

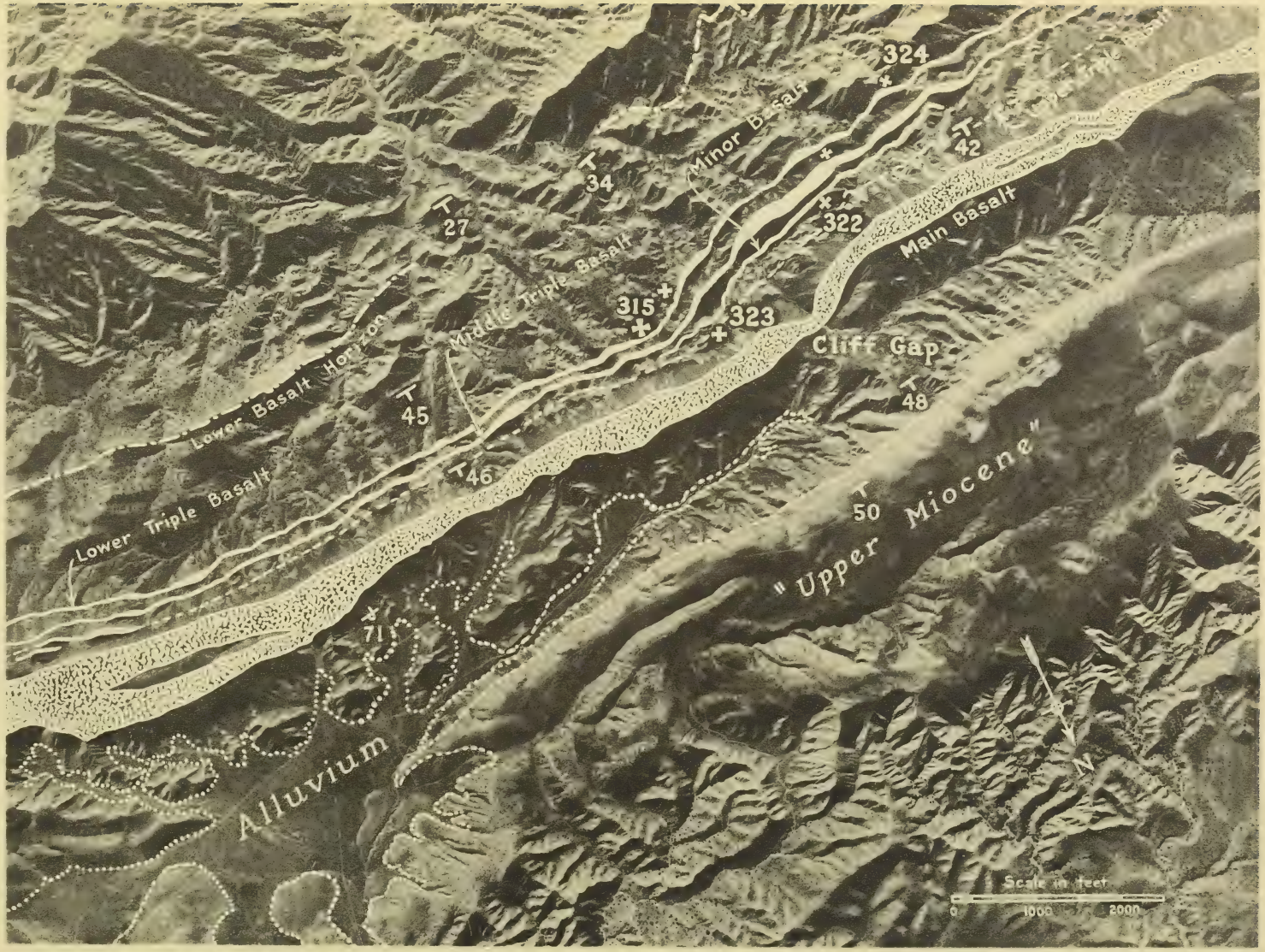
Comparative measurements (in millimeters)—continued

	1 C.I.T. No. 2686	2 A.M.N.H. No. 20530	3 C.I.T. No. 1997	4 F.A.M. No. 32207
Length, $M\bar{1}$–$M\bar{3}$	36.0	32.5	36.0	46.0
$M\bar{1}$, anteroposterior diameter	7.7	....	8.9	....
$M\bar{1}$, transverse diameter	5.3	....	5.3	....
$M\bar{2}$, anteroposterior diameter	9.5	....	11.4	....
$M\bar{2}$, transverse diameter	5.8	....	5.9	....
$M\bar{3}$, anteroposterior diameter	18.0	14.0	17.3	23.0
$M\bar{3}$, transverse diameter	6.0	....	4.7	....
Depth of jaw below first lobe of $M\bar{3}$	22.0	....	16.2	34.0†
	C.I.T. No. 3687			
Crown height of last lobe of unworn $M\bar{3}$	30.0	....	21.0†	31.0*

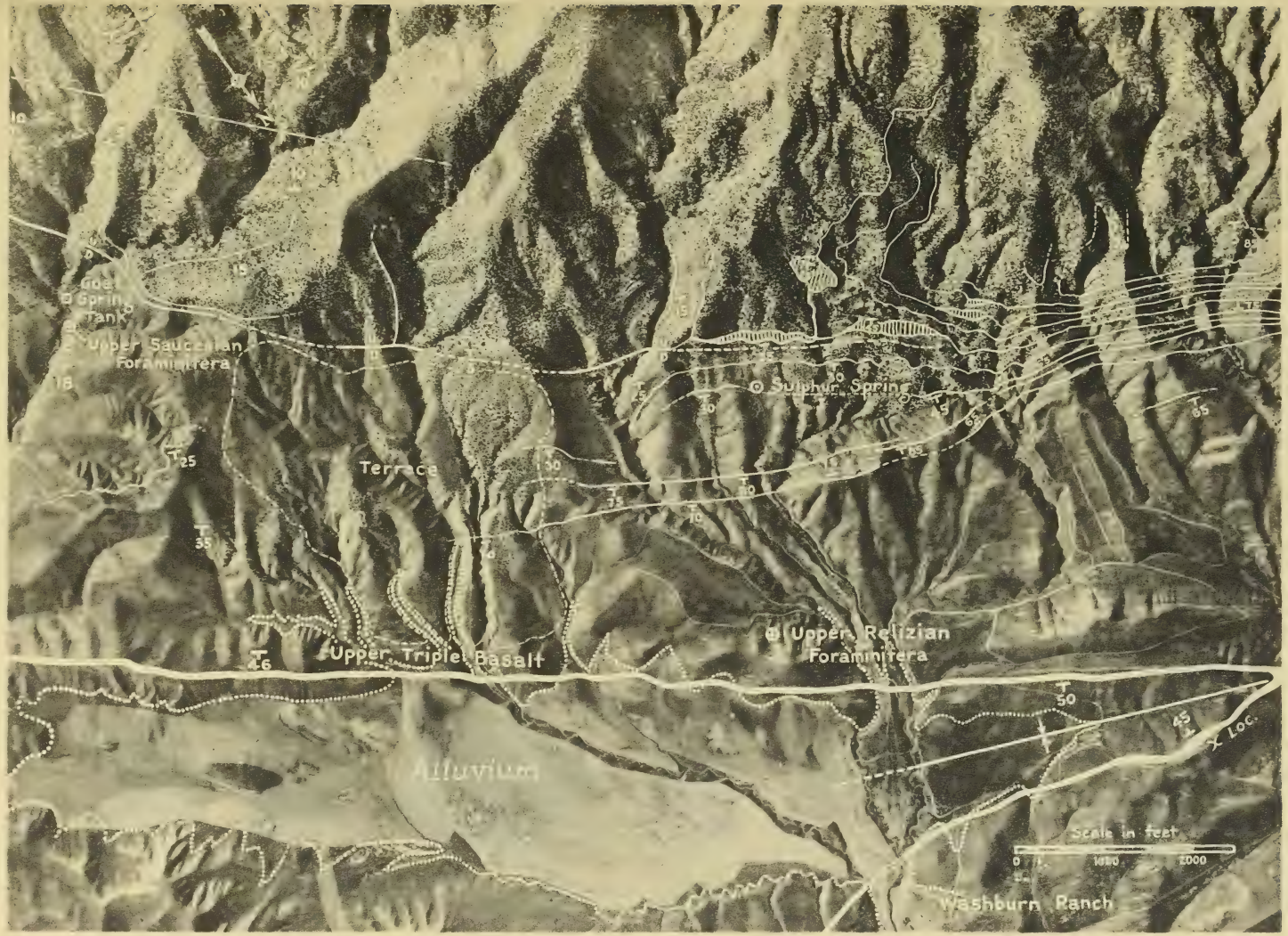
* Measurements after Frick.
† Approximate.



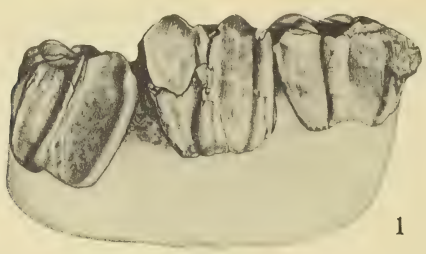
Aerial photograph of Padrones and Jerd Spring area, showing stratigraphic relations of beds and position of C.I.T. Vert. Pale. fossil localities; Caliente Mountain, California.



Aerial photograph of Cliff Gap area, showing stratigraphic relations of beds and position of C.I.T. Vert. Pale. fossil localities; Caliente Mountain, California.



Aerial photograph of Washburn Ranch area, showing stratigraphic and structural relations of Tertiary beds and position of fossil foraminiferal localities; Caliente Mountain, California.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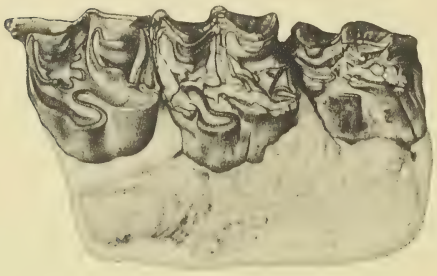
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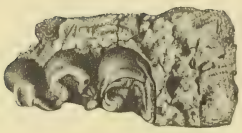
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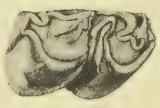
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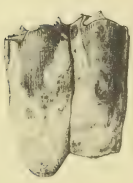
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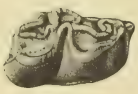
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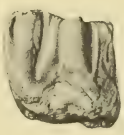
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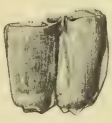
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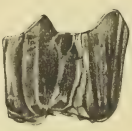
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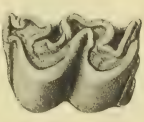
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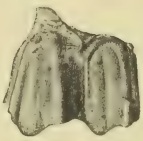
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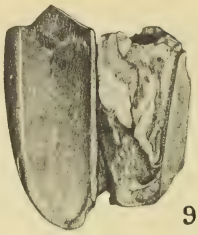
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Plate 4

Merychippus carrizoensis, n. sp.

Figs. 1, 1*a*. Type specimen, M1–M3, No. 2552. Fig. 1, outer view; fig. 1*a*, occlusal view.

Figs. 2, 2*a*. M3, No. 2570. Fig. 2, occlusal view; fig. 2*a*, outer view.

Figs. 3, 3*a*. P3, No. 2573. Fig. 3, occlusal view; fig. 3*a*, outer view.

Figs. 4, 4*a*. P2, No. 2581. Fig. 4, occlusal view; fig. 4*a*, inner view.

Figs. 5, 5*a*. M2, No. 2579. Fig. 5, occlusal view; fig. 5*a*, outer view.

Figs. 6, 6*a*. P4, No. 2575. Fig. 6, inner view; fig. 6*a*, occlusal view.

Figs. 7, 7*a*. P3, No. 2558. Fig. 7, occlusal view; fig. 7*a*, outer view.

Figs. 8, 8*a*. P4, No. 2560. Fig. 8, occlusal view; fig. 8*a*, outer view.

Merychippus stevensi, n. sp.

Fig. 9. Right molar (?), No. 2554, outer view; crown height approximately ⅙ worn.

All figures approximately × 1.
Calif. Inst. Tech. Vert. Pale. Coll., from locality 315.
Middle Miocene, Caliente Mountain, California.

Plate 5

Parahippus (?) sp.

Figs. 1, 1*a*, 1*b*. Portion of left ramus with $P\overline{4}$–$M\overline{2}$, No. 2586. Fig. 1, inner view; fig. 1*a*, occlusal view; fig. 1*b*, outer view.

Merychippus stevensi, n. sp.

Figs. 2, 2*a*. $M\underline{1}$, No. 2555. Fig. 2, outer view; fig. 2*a*, occlusal view.

Figs. 3, 3*a*. $P\underline{4}$, No. 2557. Fig. 3, outer view; fig. 3*a*, occlusal view.

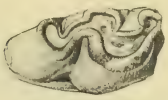
Figs. 4, 4*a*. $Dp\underline{3}$, No. 2562. Fig. 4, outer view; fig. 4*a*, occlusal view.

Figs. 5, 5*a*. $M\underline{3}$, No. 2571. Fig. 5, occlusal view; fig. 5*a*, outer view.

Figs. 6, 6*a*. Type specimen, $M\underline{1}$ or $M\underline{2}$, No. 2582. Fig. 6, occlusal view; fig. 6*a*, niner view.

All figures approximately × 1.
Calif. Inst. Tech. Vert. Pale. Coll.
Middle Miocene, Caliente Mountain, California.

1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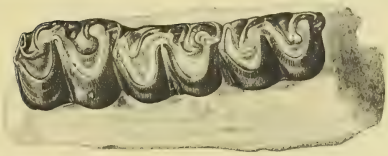
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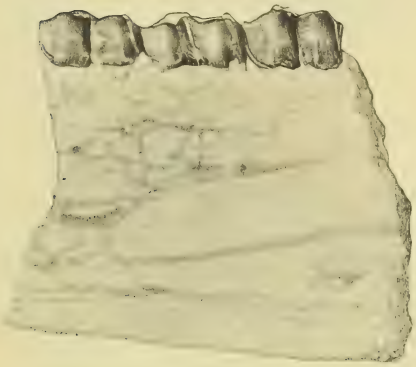
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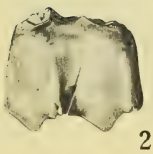
2

3

4

2a

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4a

1
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Plate 6

Merychyus calimontanus, n. sp.

Fig. 1. Left half of palate with upper dentition, I′–M$\overline{3}$, No. 2543. × 1.

Fig. 2. Right calcaneum, No. 2543, lateral view. × 1.

Fig. 3. Proximal phalanx, No. 2543, dorsal view. × 1.

Fig. 4. Left astragalus, No. 2543, dorsal view. × 1.

Fig. 5. Right 4th metatarsal, No. 2543. × app. 1.

Figs. 6, 6*a*. Portion of left ramus with P$\overline{4}$–M$\overline{3}$, No. 2544. Fig. 6, lateral view; fig. 6*a*, occlusal view. × 1.

Calif. Inst. Tech. Vert. Pale. Coll.
Middle Miocene, Caliente Mountain, California.

Plate 7

Ticholeptus (?), sp.

Fig. 1. Fragmentary skull, No. 2550, lateral view. × ½.

Merycoidodont sp. *a*

Figs. 2, 2*a*. $M\overline{2}$ (?), No. 2548. Fig. 2, occlusal view; fig. 2*a*, outer view. × 1.

Merycoidodont sp. *b*

Figs. 3, 3*a*. $M\overline{1}$, No. 2587. Fig. 3, occlusal view; fig. 3*a*, outer view. × 1.

Dromomeryx (?) sp.

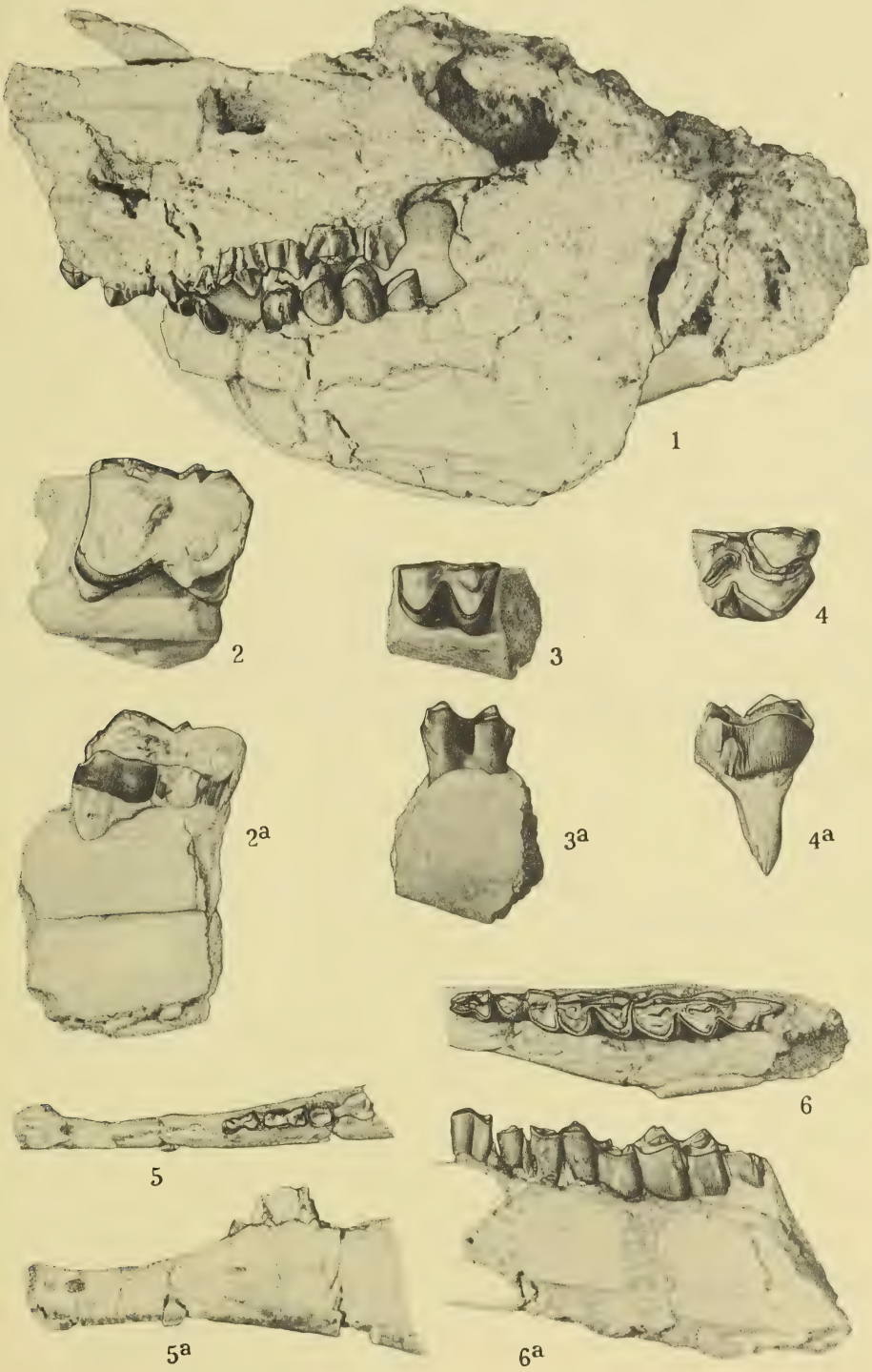
Figs. 4, 4*a*. $M\overline{2}$ (?), No. 2549. Fig. 4, occlusal view; fig. 4*a*, outer view. × 1.

Antilocaprid sp.

Figs. 5, 5*a*. Anterior portion of left ramus with roots of $P\overline{2}$–$P\overline{4}$, No. 642. Fig. 5, occlusal view; fig. 5*a*, outer view. × 1.

Figs. 6, 6*a*. Posterior portion of left ramus with $P\overline{4}$–$M\overline{3}$, No. 2686. Fig. 6, occlusal view; fig. 6*a*, outer view. × 1.

Calif. Inst. Tech. Vert. Pale. Coll.
Middle Miocene, Caliente Mountain, California.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CONTRIBUTIONS TO PALEONTOLOGY

IX

STRATIGRAPHY OF THE EASTERNMOST VENTURA BASIN, CALIFORNIA, WITH A DESCRIPTION OF A NEW LOWER MIOCENE MAMMALIAN FAUNA FROM THE TICK CANYON FORMATION

By Richard H. Jahns

With three plates and nine text figures

[Issued June 27, 1940]

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STRATIGRAPHY OF THE EASTERNMOST VENTURA BASIN, CALIFORNIA, WITH A DESCRIPTION OF A NEW LOWER MIOCENE MAMMALIAN FAUNA FROM THE TICK CANYON FORMATION

INTRODUCTION

The great thickness of dominantly nonmarine Tertiary strata in the eastern part of the Ventura Basin has impressed geologists since the time of the earliest surveys of the region. The younger of these strata, comprising the so-called Mint Canyon formation, have been eroded to form a great basinlike area in which numerous badland exposures occur (see fig. 1). Erosion has been due principally to the poor consolidation of the sediments and in part also to the rather scant cover of typical Sonoran vegetation. Although several earlier investigators examined these badlands, the first recorded discovery of vertebrate remains came as a result of reconnaissance mapping by Kew in 1919. In the publication that followed, a provisional list of the forms found here was furnished by Stock,[1] although no detailed study of the fauna was made.

After obtaining additional materials from the Mint Canyon beds, Maxson [2] in 1930 published a detailed discussion of the fauna, and agreed with Stock on an upper Miocene age for the series. He further recognized that this vertebrate assemblage not only furnishes valuable data from which an age determination of the deposits might be made, but likewise sheds light on the age of the overlying marine strata and on their correlation with continental equivalents in the Great Basin and Great Plains provinces to the east. In a subsequent critical review of the fauna, Stirton [3] reached conclusions not in accord with those of Maxson, and advocated a lower Pliocene age for the strata. Since that time, several papers [4] of a mildly controversial nature have dealt directly or indirectly with the age of the Mint Canyon and with the stratigraphic relations of the fossils involved. The non-uniform character of the fauna, in which primitive and advanced types of mammals appear to be in association, has presented an additional

[1] W. S. W. Kew, U. S. Geol. Surv. Bull. 753, p. 54, 1924.

[2] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, pp. 77–112, 1930.

[3] R. A. Stirton, Amer. Jour. Sci., 5th ser., vol. 26, pp. 569–570, 1933.

[4] P. Teilhard de Chardin and R. A. Stirton, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 23, pp. 277–290, 1934. R. A. Stirton, Amer. Jour. Sci., 5th ser., vol. 32, pp. 174, 188, 1936; Jour. Paleontol., vol. 13, pp. 135–136, 1939. P. O. McGrew and G. E. Meade, Amer. Jour. Sci., 5th ser., vol. 36, pp. 197–207, 1938. G. E. Lewis, Amer. Jour. Sci., 5th ser., vol. 36, pp. 208–211, 1938. J. H. Maxson, "Miocene-Pliocene boundary" (abstract), Bull. Amer. Assoc. Petrol. Geol., vol. 22, pt. 2, pp. 1716–1717, 1938. J. H. Maxson, Bull. Geol. Soc. Amer., vol. 49, no. 12, pt. 2, pp. 1916–1917, 1938. J. E. Eaton, Bull. Amer. Assoc. Petrol. Geol., vol. 23, pp. 533–534, 1939.

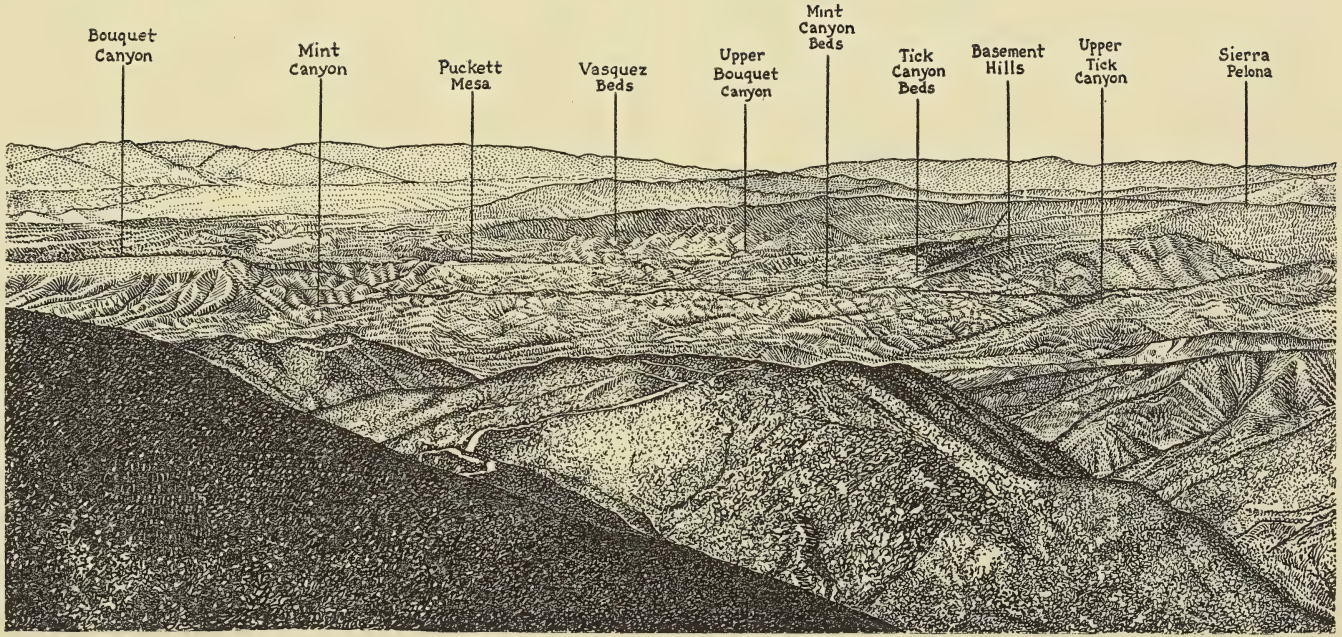


FIG. 1. The Mint Canyon area as viewed from Santa Clara Ridge in the San Gabriel Mountains to the southeast. The higher regions are composed of crystalline rocks; the basinlike lowlands have been eroded out of softer sedimentary rocks. Note the Vasquez and Tick Canyon beds lapping against the darker-colored granitic basement in the middle distance.

complication. Both Maxson and Stirton have commented [5] on this peculiar feature, although no stratigraphic break has been noted in the section.

That disagreement continues to exist in regard to the stratigraphy of the Mint Canyon area is not surprising, chiefly for three reasons, as follows:

1. Not only are the vertebrate remains fragmentary and poorly preserved, but there is a paucity of forms comparable to those of other known vertebrate horizons.

2. The orogenic disturbances active in this region during Tertiary time have created structural complexities, the true nature and extent of which become apparent only after detailed geologic study. Although in regions of flat-lying strata the plotting of fossil localities on a topographic map suffices to create a clear picture of the actual field relations, such a procedure in the highly folded and faulted Mint Canyon area has been of little value. Further, the irregular lateral lithologic gradations characteristic of the fossiliferous strata greatly reduce the number of available marker beds and key horizons. As a consequence, there has been a lack of definite data on the stratigraphic position of each form.

3. The generalized character of the geologic mapping previously done, as well as some confusion in the literature, has thrown doubt on the position and relations of the Mint Canyon beds and adjacent formations, particularly the overlying marine strata. That a fuller understanding of these relations is essential to a successful marine-nonmarine correlation naturally follows.

NATURE AND SCOPE OF PRESENT INVESTIGATION

In an attempt to obtain a clearer concept of Mint Canyon stratigraphy and to determine definitely the field relations between marine and nonmarine beds, the writer devoted some forty-five field days to reconnaissance observations and to detailed mapping of a "critical area" in the basin. This area is approximately 15 square miles in extent; it includes nearly all the important known vertebrate localities, many of the badland exposures most promising as potential sources of additional material, and a significant part of the contact between the Mint Canyon and overlying marine strata. The detail of the mapping has permitted a determination of the relative stratigraphic position of each fossil occurrence within narrow limits.

The collection by H. D. Curry, Dr. J. H. Maxson, and R. W. Wilson of oreodont, equid, and rodent remains from the lowermost beds of the Mint Canyon furnished the best basis for analyzing the problem of the "mixed fauna." The fossil types were kindly turned over to the writer for study by Dr. Maxson, and the results obtained are presented in this paper with newly acquired stratigraphic data. No further review of forms previously obtained from beds higher in the section is attempted, inasmuch as pertinent detailed discussions are available in the existing literature.[6]

[5] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, pp. 81, 85, 1930. R. A. Stirton, Amer. Jour. Sci., 5th ser., vol. 26, p. 575, 1933; vol. 32, p. 188, 1936.

[6] J. H. Maxson, *op. cit.*, 1930. R. A. Stirton, *op. cit.*, 1933.

ACKNOWLEDGMENTS

The present investigations were made under the direction of Dr. Chester Stock, to whom the writer is greatly indebted, not only for his invaluable advice and suggestions and his critical examination of the manuscript, but for his continued interest in all phases of the problem. Dr. J. H. Maxson made available the new fossil material from the lower Mint Canyon beds and furnished valuable information on the invertebrate fauna collected by him from the overlying marine strata. Sincere appreciation is also expressed for the advice and criticism given by E. L. Furlong and J. F. Dougherty, and by Dr. R. W. Wilson, who studied the rodents of the new fauna. L. W. Davenport, R. E. Wallace, and W. T. Potter, Jr., gave generously of their time in helpful field assistance. The illustrations have been prepared or supervised by D. P. Willoughby.

LOCATION

The easternmost portion of the Ventura Basin, discussed in this paper, is located in the northwestern part of Los Angeles County, California, and is drained by the upper Santa Clara River and its tributaries (see fig. 2). Most important of the latter are Bouquet, Mint, and Tick Canyons, which join the Santa Clara Valley on its north side. Although hilly and rough

FIG. 2. Index map of a part of southern California, showing location of the eastern part of the Ventura Basin. The stippled rectangle represents the area shown in figure 3.

in detail, the topography is rather subdued when compared with that of the San Gabriel Mountains immediately to the south. Lying within this part of the basin, in the main between Mint and Bouquet Canyons (Humphreys Quadrangle, U. S. Geol. Surv.), is the smaller area which was mapped in detail (see hachured area in fig. 3). C.I.T. Vert. Pale. Loc. 201, the quarry from which most of the new fossil material was obtained, is situated near the narrows of Vasquez Canyon, a tributary of Bouquet Canyon, at a distance of approximately 10 miles by road from Saugus, a small town on the Southern Pacific Railroad.

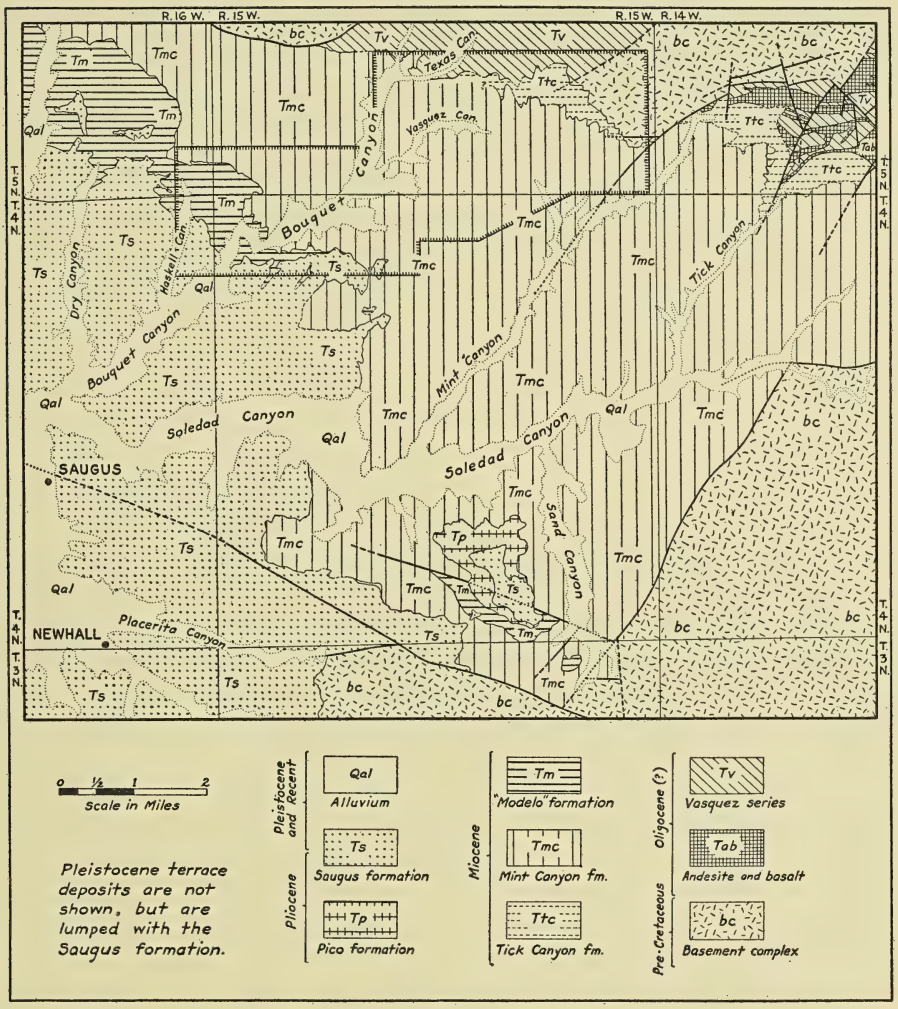


FIG. 3. Geologic map of a part of the Mint Canyon area, easternmost Ventura Basin; after Kew, with modifications by C. T. Smith and R. H. Jahns. The area with irregular outline in the northern part of the map and traversed by Bouquet Canyon is that shown in the large geologic map (fig. 4).

STRATIGRAPHY

General Statement

The easternmost Ventura Basin consists of a pre-Cretaceous crystalline basement complex, over part of which lies a thick section of predominantly nonmarine Tertiary sedimentary rocks. The basinlike distribution of these rocks north of the Santa Clara River makes for a general decrease in age of exposed units from the north and east to the south and west. A steadily progressive decrease in degree of consolidation of the sediments is also evident as one passes upward through the Tertiary section. Although large-scale faulting is very common in the region, a sufficient number of depositional contacts are available to prove an unconformity between each formation and the succeeding one in the accompanying chart.

Age	Unit
Pleistocene and Recent	Alluvial sands and gravels Terrace gravels
Pliocene	Saugus formation
Miocene	"Modelo" formation
	Mint Canyon formation
	Tick Canyon formation
Oligocene ?	Vasquez series
Pre-Cretaceous	Crystalline basement complex

The mammalian species collected in the lowermost Mint Canyon beds demonstrate the presence of a distinctly older horizon than has been hitherto ascribed to the series. There is necessarily implied not only a greater age range, but the presence of at least two formations within that part of the section heretofore mapped as Mint Canyon. This is corroborated by stratigraphic evidence obtained during the course of the detailed mapping. It has been suggested,[7] therefore, that the older, lowermost beds be termed the Tick Canyon formation,[8] and that for the remaining land-laid beds, which constitute the bulk of the section, the name Mint Canyon formation be retained. For the section as a whole, Mint Canyon series appears to be a suitable term, and should apply to all areas previously mapped as Mint Canyon formation but in which there is reason to suspect the presence of strata of Tick Canyon age.

[7] R. H. Jahns, Amer. Jour. Sci., 5th ser., vol. 37, p. 819, 1939.

[8] The name Tick Canyon is assigned because of excellent exposures about ½ mile down the canyon from an abandoned borax mine at the head of Tick Canyon, as well as in the vicinity of the Tick Canyon–Mint Canyon divide (Lang Quadrangle, U. S. Geol. Surv.). The type section, however, is located between Mint and Vasquez Canyons in the Humphreys Quadrangle (see figs. 3, 4).

Crystalline Basement Complex

The extreme complexity of the so-called basement complex is typical of most ancient terranes in which metamorphic rocks have become intimately associated with later igneous intrusives. One large exposure of these rocks, a westward prong of the Sierra Pelona (see fig. 1), appears in the Mint-Bouquet Canyon area. The dominant type is the fine-grained, bluish-gray rock known as the Pelona schist; with it are associated minor amounts of quartzite, hornblende-rich schist, and phyllite. Into the metamorphics has been injected much granitic material, giving rise to many masses of migmatitic rocks. Chief among these are "spotted diorites" and porphyroblastic gneisses. A few small bodies of syenite and granodiorite are also present. Little can be said concerning the age of these rocks except that they are considered as pre-Cretaceous, a view based on their injection by supposedly Sierran plutonics.

Vasquez Series

Cropping out in a large area between Bouquet and Vasquez Canyons are the coarse, light-colored sandstones and conglomerates doubtfully referred by Kew [9] to the Sespe, but called the Escondido series by Hershey [10] and Simpson.[11] More recently, Sharp [12] has suggested the name Vasquez in place of Escondido, which is preoccupied; his usage is followed in this discussion. These coarse, massive sediments are faulted against the basement complex in Vasquez Canyon, but lie with depositional contact upon the crystallines in the type area to the east (Ravenna Quadrangle, U. S. Geol. Surv.). South and east of Mint Canyon these deposits increase in coarseness and degree of consolidation, and appearing with them are interbedded flows and sills of andesite and basalt. A distinct reddish color becomes characteristic.

Available data indicate a localized fault-block basin of deposition for the 9000 feet of Vasquez beds, with transportation of material subaerially for short distances from rather steep source slopes. The general trend of deposition was westward, with a gradual decrease in detrital coarseness in that direction. Intermittent periods of volcanic activity produced an additional 4000 feet of basic flows and shallow concordant intrusions. The exact age of the series is shrouded in doubt. Because all attempts to find fossils in the more promising strata have proved unsuccessful, the various postulated ages of Eocene, Oligocene, and middle Miocene have been based on non-paleontological evidence. A doubtful Oligocene assignment is here made; a detailed discussion follows in the section dealing with the age of the Mint Canyon.

[9] W. S. W. Kew, U. S. Geol. Surv. Bull. 753, pp. 38–39, 1924.
[10] O. H. Hershey, Amer. Geologist, vol. 29, pp. 349–372, 1902.
[11] E. C. Simpson, Calif. Jour. Mines and Geol., vol. 30, pp. 391–395, 1934.
[12] R. P. Sharp, Pan Amer. Geologist, vol. 63, p. 314, 1935.

Tick Canyon Formation

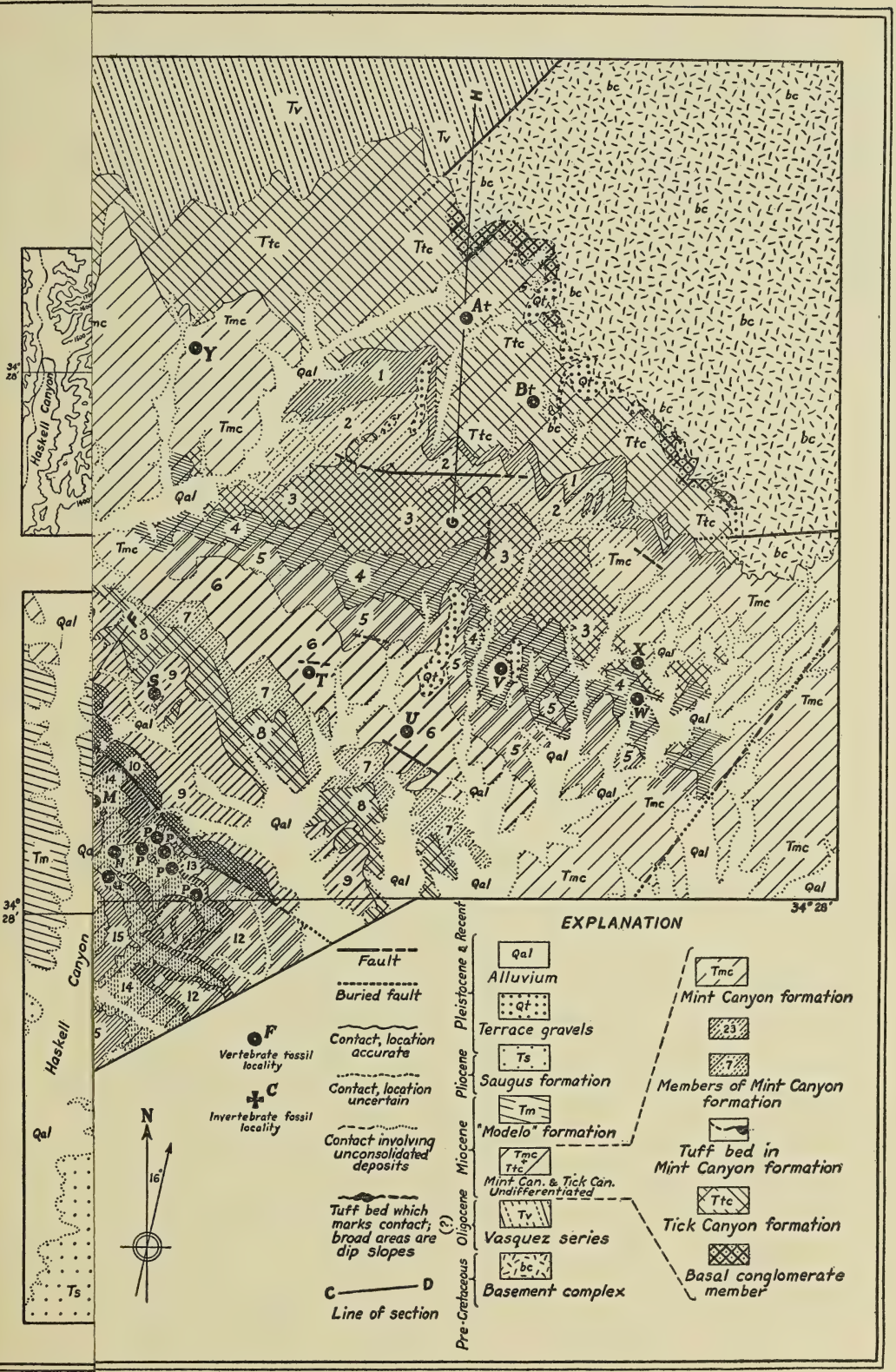
The basal beds of Hershey's Mellenia series [13] and Kew's Mint Canyon formation [14] are traceable in a narrow, irregular band extending from the Tick Canyon area northwesterly to a point between Vasquez and Texas Canyons, where lack of exposures prevents their demarcation from the overlying Mint Canyon strata. At the type section near locality 201 (locality *Bt* on geologic map, fig. 4) the formation consists of 593 feet of reddish-brown clay, siltstone, and sandstone, with a thick, irregular zone of poorly lithified boulder to cobble conglomerate at the base (see measured section on page 163). Nearly everywhere else, it is much thinner, with an average thickness of approximately 350 feet; in at least one locality, it appears to wedge out entirely between the Mint Canyon and the basement complex. The fine-grained, evenly laminated character of certain beds, as well as the local worm borings which the sediments contain, suggests a lacustrine origin; the bulk of the section, however, is fluviatile.

For a distance of more than a mile between Mint and Vasquez Canyons, the very coarse basal beds of the Tick Canyon formation lap against the basement complex on a steeply dipping depositional contact. The attitude and coarseness of these beds, as well as the angularity and lack of sorting of their contained fragments, indicate deposition at the base of a very steep slope, with transportation of sediment for only a limited distance. Similar relations exist between the Tick Canyon and the Vasquez series, although the contact is not so clearly exposed. That at least a part of the Vasquez formed highlands during Tick Canyon time is shown by the presence in the latter of fragments of a peculiar volcanic breccia characteristic only of the upper Vasquez.

Mint Canyon Formation

Inasmuch as the Mint Canyon beds have an aggregate thickness of about 4000 feet, and have generally less steep attitudes than either of the above-noted formations, it is scarcely surprising that the exposures of this formation have a considerable areal extent (see fig. 3). Its general lithologic characters have been discussed by Kew [15] and Maxson,[16] who indicated a division of the section into two main parts. For purposes of structural interpretation and stratigraphic location, the writer has made a 27-fold subdivision of the Mint Canyon formation. Each member represents a time, rather than lithologic, unit, and its distribution has been traced, so far as possible, by marker beds or exposures sufficiently clear for recognition as time boundaries within areas of changing lithology. The following measured section illustrates the typical distribution of rock types throughout the 27 members; their areal pattern appears on the geologic map (fig. 4).

[13] O. H. Hershey, *op. cit.*, pp. 356–358, 1902.
[14] W. S. W. Kew, *op. cit.*, p. 52, 1924.
[15] *Ibid.*, pp. 52–53, 1924.
[16] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, p. 81, 1930.


Tv
Ttc
Tmc
Qal
bc
Qt
Ts
Tm
At
Bt
Haskell Canyon
34° 28'
EXPLANATION
Fault
Buried fault
Contact, location accurate
Contact, location uncertain
Contact involving unconsolidated deposits
Tuff bed which marks contact; broad areas are dip slopes
F Vertebrate fossil locality
C Invertebrate fossil locality
C — D Line of section
Pleistocene & Recent
Pliocene
Miocene
Oligocene (?)
Pre-Cretaceous
Alluvium
Terrace gravels
Saugus formation
"Modelo" formation
Mint Can. & Tick Can. Undifferentiated
Vasquez series
Basement complex
Mint Canyon formation
Members of Mint Canyon formation
Tuff bed in Mint Canyon formation
Tick Canyon formation
Basal conglomerate member

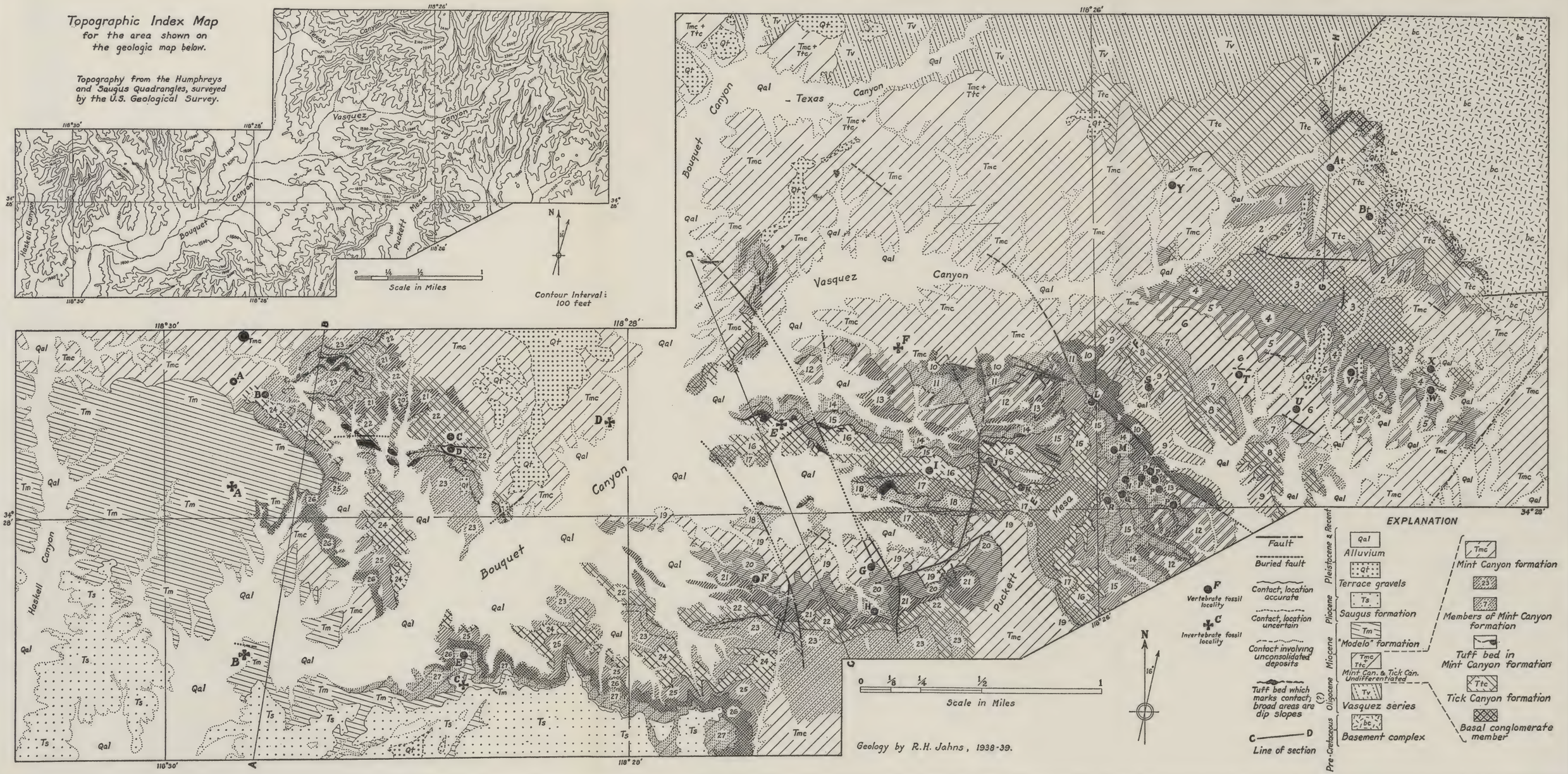


FIG. 4. Detailed geologic map of a part of the Mint Canyon area

Measured Section of Tertiary Formations from Bouquet Canyon near the New Era School to Upper Vasquez Canyon, via Puckett Mesa, California

(Section is composite, with all matched parts from areas no more than ¼ mile apart in the field.)

	Thickness (feet)	
Saugus Formation		
Sandstone and silt, rusty brown and pinkish, poorly consolidated, irregularly bedded, with local lenses of very coarse gravel	30+	
Conglomerate, light gray, sandy, cross-bedded, poorly cemented	4	
Sandstone, as above, with brownish schist-rich zones and beds of pink and red clay; poorly exposed	120	
Total thickness, Saugus formation		154+
Unconformity		
"Modelo" Formation		
Shale, sandy, buff to brown, thin-bedded, with reddish-brown concretionary structures	14	
Sandstone, buff and tan, arkosic, very friable, locally gypsiferous, with small reddish-brown clastic dikelets	45	
Shale, gray to brown, sandy, with minor sandstone beds	11	
Pebble conglomerate, gray to tan, well bedded, gypsiferous	13	
Sandstone, as above, with intercalated shale and conglomerate lenses	22	
Sandstone, light gray, massive, very friable	17	
Shale, greenish gray to reddish brown, sandy, gypsiferous, locally rich in concretions, clastic dikelets, and charcoal; breaks into small blocks	56	
Sandstone, gray to brown, arkosic, friable, poorly exposed	159	
Sandstone, light gray, massive, with minor shale	134	
Cobble conglomerate, light brown, evenly bedded, very gypsiferous, with fragments of quartz, granitic and schistose rock types, silicic and intermediate volcanics, and Mint Canyon sandstone in an arkosic matrix; forms cliffs and is a good marker horizon	16	
Total thickness, "Modelo" formation		487
Unconformity		
Mint Canyon Formation		
Member 27		
Sandstone, buff to gray, well sorted but with local pebble lenses, and siltstone, greenish gray, blocky, alternating in thin layers; the whole weathers to sandy or gravelly slopes	115+	
Conglomeratic sandstone, creamy to light gray, cross-bedded, massive, broadly lenticular, with minor intercalated blocky pinkish siltstone; locally cliff-making	32	

MINT CANYON FORMATION—*Continued*		Thickness (feet)
Conglomerate, heavy and massive, rich in pebbles and cobbles of andesite and andesite breccias; forms distinct cliff	7	
Total thickness, member 27		154+
Member 26		
Conglomeratic sandstone, light gray, and siltstone, greenish gray to buff, blocky, not massive, alternating in thick layers with the latter subordinate; locally resistant	28	
Siltstone and clay, dominantly buff, pinkish, and greenish, sandy, well bedded; scattered vertebrate fossils	38	
Pebble conglomerate, continuous, moderately well sorted, rich in subrounded andesite and schist fragments	5	
Total thickness, member 26		71
Member 25		
Sandstone, silty and locally pebbly, creamy gray, with intercalated thin, hard, persistent, flaggy brown arkosic sandstone; forms smooth-faced cliffs	71	
Vitric tuff, friable, pearly gray with bluish cast, medium-grained, granular but not gritty; associated with tuffaceous sandy beds; exposed only locally	4	
Total thickness, member 25		75
Member 24		
Conglomerate, very sandy, creamy gray, blocky, with sandy lenses; forms cliffs	5	
Siltstone and clay, brown, tan, and pinkish, with flaggy interbeds of hard brown sandstone; scattered vertebrate remains (C.I.T. Loc. 101)	17	
Cobble conglomerate, brown to gray, well bedded, rich in fragments of basement complex; forms vertical, smooth-surfaced cliffs	23	
Siltstone and clay, as above	34	
Cobble conglomerate, white to gray, otherwise as above	13	
Total thickness, member 24		92
Member 23		
Siltstone, locally sandy and pebbly, tan, gray, pink, and brown, with subordinate conglomerate, coarse-grained, creamy gray to white, rich in andesite and granite fragments; the whole poorly exposed	240±	
Vitric tuff, granular, fine- to medium-grained, bluish gray, in part friable; highly lenticular and poorly exposed	3	
Sandstone, hard, brown, irregularly jointed, arkosic, and with local mafic-rich lenses	2	

		Thickness (feet)
Conglomerate, poorly cemented, coarse-grained, rich in andesite, volcanic breccia, and schist fragments, with sandstone and sandy siltstone, white to buff, weathering into soily slopes; upper part poorly exposed	82	
Vitric tuff, as above	4	
Sandstone, hard, brown, as above	2	
Total thickness, member 23		333±
Member 22		
Boulder conglomerate, gray, massive, poorly sorted, resistant	14	
Sandstone, gray, coarse, and conglomeratic, regularly bedded, with local lenses of light gray cobble conglomerate; cliff-making horizon	35	
Siltstone, tan to gray, sandy, blocky; blocks exfoliate, then crumble to soily masses; irregularly fossiliferous (C.I.T. Loc. 99)	42	
Cobble and pebble conglomerate, cross-bedded, light gray to white, with associated channel sandstones, gray, friable, lenticular	28	
Total thickness, member 22		119
Member 21		
Siltstone, pinkish, tan, and greenish gray, with sandy lenses rich in clay nodules; scattered beds of conglomeratic sandstone, well sorted, vertically jointed, resistant	33	
Sandstone, arkosic, coarse, well sorted, with subordinate siltstone, tan and greenish; forms cliff	24	
Sandstone, creamy gray, massive, resistant, with silty partings	11	
Total thickness, member 21		68
Member 20		
Siltstone, buff, bluish gray, and pinkish, sandy, evenly bedded, and sandstone, conglomeratic, massive, cliff-making, alternating in thick layers; forms local badlands with scattered vertebrate fossils	91	
Vitric tuff, bluish gray, friable to blocky, lenticular, poorly exposed	3	
Sandstone, brown, hard, ripple-marked, flaggy	3	
Total thickness, member 20		97
Member 19		
Siltstone, light gray to tan, evenly bedded, with thin sandy and pebbly layers; forms smooth-faced vertical cliffs	58	
Sandstone, pebbly, light gray, cross-bedded, well sorted, massive	8	

Mint Canyon Formation—*Continued*		Thickness (feet)
Siltstone, light gray to pinkish brown, regularly bedded, with few resistant layers; forms badlands, sparsely fossiliferous (C.I.T. Loc. 102)	51	
Total thickness, member 19		117
Member 18		
Conglomerate, heavy, massive, coarse, locally sandy	12	
Sandstone, poorly consolidated, with siltstone, light gray, thinly bedded; much less resistant than conglomerate above	34	
Total thickness, member 18		46
Member 17		
Crystal tuff, medium-grained, white to buff, delicately bedded, with associated tuffaceous sandstone; whole weathers into angular blocks	3	
Sandstone, arkosic, hard, coarse, brown, flaggy	2	
Conglomerate, light gray, heavy, resistant, with rounded pebbles and cobbles of andesite, schist, and granitic rocks; minor interbeds of sandy siltstone	38	
Crystal tuff, as above; lenticular and poorly exposed	2	
Sandstone, gray and tan, well sorted, evenly bedded, and siltstone, brown to gray, blocky, weathering into gritty soil; alternate in 1- to 6-foot layers and form steep, corrugated cliffs	55	
Conglomerate, as above	15	
Siltstone, very gritty, light gray, locally rich in clay nodules	14	
Total thickness, member 17		129
Member 16		
Pebble conglomerate, white to gray, evenly but massively bedded; weathers to gravelly slopes but forms local cliffs	23	
Siltstone, sandy to pebbly, gray; forms fluted cliffs and badlands with scanty vertebrate remains (C.I.T. Loc. 100)	58	
Conglomerate, bouldery, poorly cemented, associated with channel sandstones	12	
Total thickness, member 16		93
Member 15		
Crystal tuff, snow white to buff, ripple-marked, delicately bedded, weathering into angular blocks; local tuffaceous sandstone, bearing plant fossils	4	
Sandstone, brown, hard, flaggy	3	
Sandstone, light gray, friable, rich in clay nodules, and local brown, flaggy arkose; subordinate siltstone, pearl gray, weathering blocky	89	

		Thickness (feet)
Boulder conglomerate, crudely bedded, cross-bedded, poorly sorted; shows cut-and-fill channel structure	6	
Total thickness, member 15		102
Member 14		
Crystal tuff, as in member 15	3	
Sandstone, brown, hard, flaggy	2	
Siltstone, very sandy, greenish to tan, and pebbly sandstone, alternating in thick layers; local vertebrate fossil accumulations (C.I.T. Loc. 103, Los Angeles Museum Loc. 1006)	15	
Sandstone, massive, friable, vertically jointed	3	
Siltstone, as above	19	
Conglomerate, typical stream-channel type	7	
Siltstone, fine-grained, yellowish to greenish gray, locally rich in vertebrate fossils (Univ. of Calif. Loc. 3564)	58	
Sandstone, bluish gray, friable, persistent	1	
Total thickness, member 14		108
Member 13		
Sandstone and siltstone, light gray, alternating regularly in 1- to 4-foot layers; form cliffs of corrugated appearance	27	
Cobble conglomerate, cross-bedded, poorly sorted, with channel-filling structures	4	
Sandstone, silty, buff to gray, friable, poorly exposed	17	
Sandstone, tan, massive, vertically jointed	5	
Total thickness, member 13		53
Member 12		
Siltstone, tan, buff, and gray, locally very sandy, with scattered interbeds of hard, flaggy brown sandstone; very poorly exposed, weathering to sandy slopes	113	
Crystal tuff, with much tuffaceous sandstone, white to light gray, hard to crumbly	2	
Total thickness, member 12		115
Member 11		
Siltstone and clay, light green, tan, pinkish, buff, and purplish, evenly and thinly bedded, highly gypsiferous, with a few flaggy interbeds of hard, brown arkosic sandstone	88	
Sandstone, buff to light gray, well sorted, very resistant	5	
Total thickness, member 11		93
Member 10		
Clay, highly colored in greens, buffs, and pinks, gypsiferous, with flaggy beds of hard brown sandstones	27	

Mint Canyon Formation—*Continued*		Thickness (feet)
Siltstone and clay, dominantly gray and brownish, with interbeds of papery brown sandstone	68	
Clay, as above	24	
Sandstone, brown, friable, tending to massive	4	
Crystal tuff, white to gray, lenticular, with much tuffaceous sandstone	1	
Total thickness, member 10		124
Member 9		
Clay, dark gray to black, crumbly	3	
Siltstone, gray to buff	11	
Siltstone, brown to maroon, with flaggy interbeds of hard brown sandstone	15	
Sandstone, light gray, blocky, impure	4	
Siltstone, maroon, gypsiferous, clayey	30	
Sandstone, as above	30+	
Sandstone, white to tan, and clayey siltstone, buff to maroon, alternating in thin beds; lower part poorly exposed, sparsely fossiliferous (Univ. of Calif. Loc. 3571)	142+	
Total thickness, member 9		235+
Member 8		
Siltstone, gray, clayey	15	
Siltstone, pearl gray, brown, and greenish, gritty	14	
Sandstone, tan, blocky, with conglomerate zone at base	5	
Conglomerate, light gray, well bedded, with silty matrix	17	
Sandstone, gray, coarse, arkosic, with minor pebble conglomerate, rich in fragments of granitic crystallines, andesites, and volcanic breccias; whole weathers to sandy and gravel-strewn slopes	87	
Total thickness, member 8		138
Member 7		
Siltstone, light tan to pinkish, thinly bedded, weathering into soily slopes	43	
Sandstone, arkosic, brown, blocky to flaggy	3	
Siltstone and sandstone, tan and gray, fine to coarse, the whole very heterogeneous	46	
Sandstone, as above	3	
Siltstone, sandy, white to pinkish, seriate but generally fine-grained	41	
Conglomerate, white, poorly cemented, well stratified, with cobbles of the usual igneous rocks	5	
Siltstone, sandy, as above	46	
Siltstone, sandy to clayey, dominantly pinkish, fine-bedded; forms local badlands	10	
Total thickness, member 7		197

	Thickness (feet)	
Member 6		
Siltstone, pinkish, and sandstone, whitish, interbedded intimately; rich in clay nodules and vivianite smears; the whole nonresistant and poorly exposed, with local badlands carrying scattered vertebrate remains (Univ. of Calif. Loc. 3555)	138	
Sandstone, tan to gray, friable, arkosic; weathers to soily slopes	104	
Conglomerate, chalky red, massive with sandy lenses, locally cross-bedded; prominent marker bed but not persistent	9	
Sandstone, as above	49	
Conglomerate, white, poorly cemented, with rounded cobbles of granitic rocks	4	
Siltstone and clay, pearl gray, smoky gray, tan, pink, purple, and brown, heavily gypsiferous, fine-grained, thin-bedded, rich in white clay nodules; locally forms badlands	152	
Total thickness, member 6		456
Member 5		
Sandstone, light gray to tan, very impure, poorly cemented, with many resistant flaggy beds, arkosic, brown, very evenly spaced in section	145	
Clay, greenish, tan, purple, pinkish, buff, and brown, gypsiferous, and conglomerate, light brown, alternating fairly regularly; whole becomes very red locally	26	
Total thickness, member 5		171
Member 4		
Sandstone, white, coarse, friable	4	
Clay and siltstone, greenish, pinkish, tan, brown, and dark gray, gypsiferous; forms slumped slopes and isolated badlands	56	
Siltstone, pinkish to brownish, blocky, with thin, resistant, flaggy sandstone lenses; bears scanty vertebrate fossil remains	83	
Sandstone, brownish, impure, friable, poorly exposed	75	
Cobble conglomerate, brown, well cemented, well stratified, cross-bedded; forms cliffs	8	
Total thickness, member 4		226
Member 3		
Sandstone, reddish brown, massive, impure, and pebble conglomerate, thinly bedded, well cemented, alternating in thick layers	52	
Siltstone, gray to tan, blocky, with flaggy sandstone, thin, brown, arkosic	51	
Sandstone, as above	145	

		Thickness (feet)
MINT CANYON FORMATION—*Continued*		
Pebble conglomerate, chalky reddish brown, massive, well cemented, locally sandy, rich in schist fragments; forms cliff	15	
Sandstone, reddish brown to ocherous, arkosic, with minor pebble conglomerate and siltstone	112	
Pebble conglomerate, chalky reddish brown, well sorted, evenly stratified, locally cross-bedded, moderately well cemented, with local lentils of arkosic sand; forms ridges and cliffs	27	
Total thickness, member 3		402
Member 2		
Siltstone, brown and reddish brown, sandy, poorly exposed	34	
Conglomerate, light gray, poorly cemented, well bedded	11	
Sandstone, reddish brown, conglomeratic, arkosic, friable, poorly exposed	87	
Conglomerate, gray to brownish, thinly but irregularly bedded, persistent, resistant, rich in schist fragments	4	
Total thickness, member 2		136
Member 1		
Conglomerate, chalky brown, heavily bedded, rich in flaggy schist fragments, and conglomeratic sandstone, friable, arkosic, alternating in 6- to 10-foot layers; whole forms local cliffs	94	
Total thickness, member 1		94
Total thickness, Mint Canyon formation		4044±
Unconformity		
TICK CANYON FORMATION		
Sandstone, uniformly reddish brown, friable, with minor silty and soily beds; poorly exposed, but forms badlands locally	158	
Conglomerate, tan to reddish brown, cross-bedded, poorly cemented	6	
Sandstone, as above; siltstone, ocherous to reddish brown, thinly laminated, gypsiferous; and scattered thin beds of sandy shale, compact, reddish to greenish brown, with casts of worm borings	110	
Conglomerate, light gray, poorly consolidated, pebbles and cobbles subrounded, white arkosic cement	12	
Sandstone, as above, but with more pebbly and flaggy beds	68	
Siltstone, reddish brown, compact, evenly and thinly bedded, with minor flaggy sandstone and greenish clay; locally fossiliferous (C.I.T. Loc. 201)	55	
Clay and siltstone, red, tan, olive green, yellow, and brown, fine-grained, highly gypsiferous, poorly exposed	75	
Sandstone and arkose, reddish brown, crumbly, poorly sorted	15	

	Thickness (feet)
Cobble to boulder conglomerate, tan to gray, poorly bedded, sorted, and lithified, with large fragments of underlying basement rocks	94
Total thickness, Tick Canyon formation	593

Unconformity

BASEMENT COMPLEX

Mica schist, syenite, granodiorite, quartzite, and miscellaneous migmatitic rock types

TOTAL THICKNESS OF SEDIMENTARY SECTION ... 5278±

It will be noted that the beds in the lower half of the section (members 1 to 11) are characteristically fine-grained, thin-bedded, and of variegated colors, whereas those higher up are more irregular, coarser, and subdued in color. Vertebrate remains seem to occur in horizons having a rather even vertical distribution, although the upper horizons yield a greater abundance of material. Another gradation of unusual interest is that between the coarse fluviatile sandstones and conglomerates adjacent to Puckett Mesa on the southeast and their fine-grained, evenly bedded lacustrine counterparts to the northwest. This is particularly well shown at the base of member 15, where within a distance of a half-mile a heavy channel conglomerate passes laterally without break through a littoral sandstone zone into thinly bedded lacustrine silts and clays. That such a relation actually exists is demonstrated by a prominent light-colored marker bed of water-laid tuff, which lenses out immediately beneath the conglomerate. The relative distribution of fluviatile and lacustrine strata in the vicinity of Bouquet Canyon is shown in figure 5; section *CD* in figure 6 illustrates the gradational phenomenon mentioned above.

Greenish to gray silty beds in the lacustrine section contain numerous fresh-water gastropod remains, chief among which is the species *Paludestrina imitator* Pilsbry.[17] Localities where these mollusks are conspicuous are recorded in figures 4 and 5. The occasional vertebrate fragments found with them are confined to the margins of the large lacustrine basin (see fig. 5). Detailed mapping of the silty deposits, especially their tracing across the broadly alluviated Bouquet Canyon, was made possible by the presence in the section of several marker beds of white to gray tuff and tuffaceous sandstone. These beds, because they are confined in their extent to the regions of soft lake deposits, stand out clearly and form the ridges in the present topography.

The Mint Canyon formation overlies the older Tick Canyon in all places where the latter is exposed. In the vicinity of locality 201 an angular unconformity is suggested between the two; two small folds and associated

[17] W. S. W. Kew, U. S. Geol. Surv. Bull. 753, p. 54, 1924.

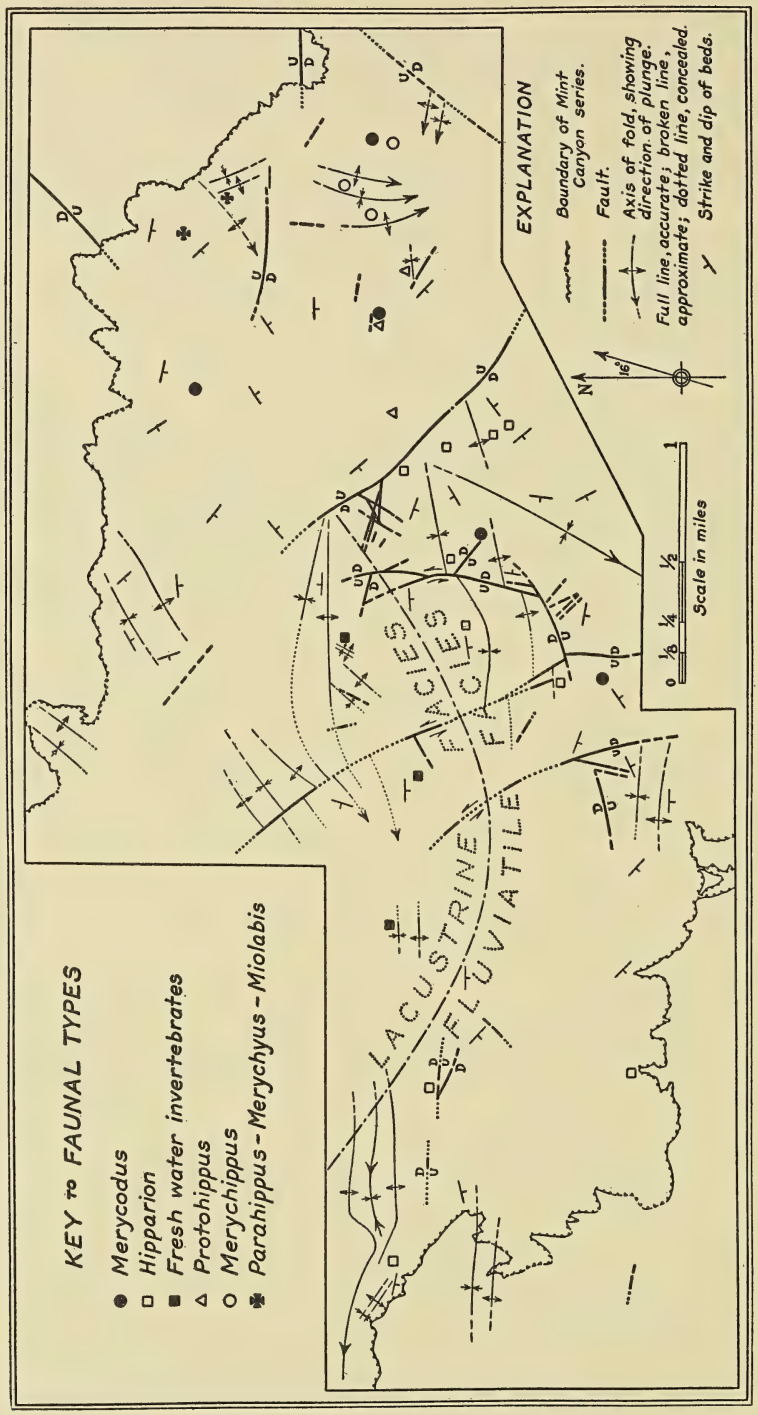


FIG. 5. Outline of that portion of the Mint Canyon region mapped in detail (see fig. 4), showing structural axes and distribution of faunal types.

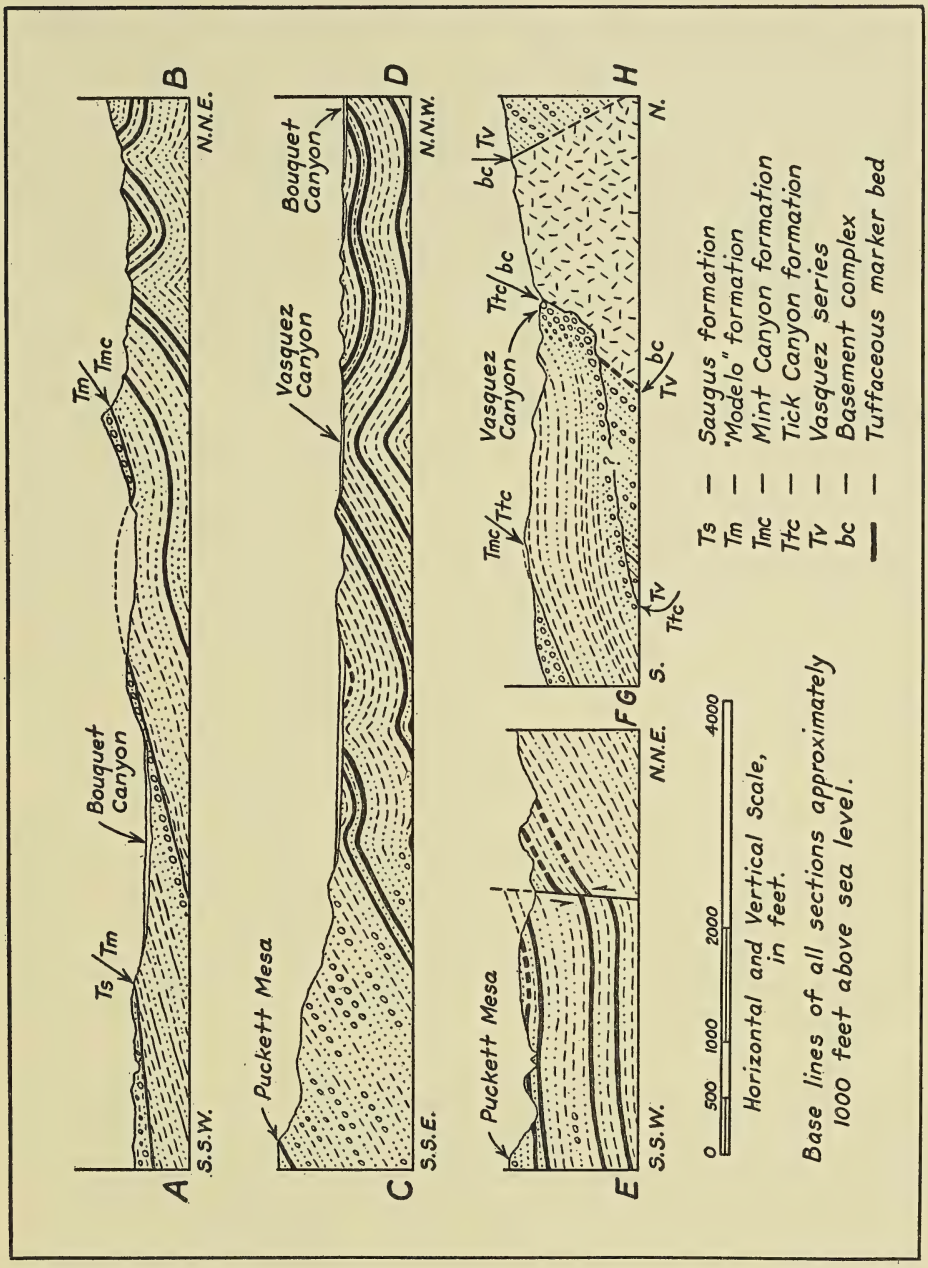


FIG. 6. Structure sections across parts of the Mint Canyon area (see fig. 4 for exact locations).

minor plications in the fine-grained older beds do not appear in the superjacent conglomeratic strata of the Mint Canyon formation. This feature, however, might be merely the result of differences in competence of the two rock types. That a sedimentary break indicated by the faunal differences does appear, probably as a disconformity, is shown by the location of the contact at the base of a thick conglomerate zone, a location fixed with certainty by fossil occurrences. Its unconformable nature is further shown by a general change in lithology (see measured section or section *GH*, figure 6) and by the irregular distribution of the Tick Canyon beds. Where these strata are not exposed, the Mint Canyon nonconformably overlies the Vasquez series, or is faulted against older rocks.

"Modelo" Formation

Above the Mint Canyon lie the fossiliferous brownish sandstones and shales tentatively correlated with the Modelo by Kew.[18] Although they are equivalent to the upper part of the Modelo group, these beds are herein termed "Modelo" because they do not correspond in age to the Modelo, *stricto sensu*, of Hudson and Craig.[19] They were deposited under brackish-water and marine conditions, and are the only marine beds in the easternmost Ventura Basin north of the Santa Clara Valley. The "Modelo" is exposed over a broad area in the higher hills between Haskell and Bouquet Canyons, but pinches out between Mint Canyon strata and the overlying Saugus formation on the south side of the latter canyon.

Although Kew recorded a pronounced nonconformity between the marine and the underlying nonmarine strata, it has since been suggested [20] that the relation is one of interfingering or lateral and upward intergrading, due presumably to marine transgressive overlap. The resulting confusion has thrown serious doubt on the exact stratigraphic relations between the "Modelo" invertebrates and the Mint Canyon vertebrate horizons. That the features of the Bouquet-Haskell Canyon contact area are in no way attributable to interfingering or gradation of the type suggested, but are on the other hand characteristic of a true unconformity is denoted by the following cogent facts:

1. The base of the "Modelo" is marked by a persistent, evenly bedded cobble conglomerate member which contains fragments of Mint Canyon material. Throughout the area this conglomerate remains of surprisingly uniform thickness and is quite distinct from the underlying siltstones of the Mint Canyon formation. Its bedding is everywhere parallel with its trend.

2. Although the post-"Modelo" age of much of the folding in the Mint Canyon has resulted in essentially concordant relations between the two

[18] W. S. W. Kew, U. S. Geol. Surv. Bull. 753, pp. 67–69, 1924.

[19] F. J. Hudson and E. K. Craig, Bull. Amer. Assoc. Petrol. Geol., vol. 13, pp. 509–518, 1929.

[20] T. Clements, Bull. Amer. Assoc. Petrol. Geol., vol. 21, p. 215, 1937. R. A. Stirton, Jour. Paleontol., vol. 13, chart on p. 135, 1939.

formations, there are local discrepancies of attitude. Non-conformability is especially well shown on the west side of Haskell Canyon.

3. The detailed mapping has revealed a north-northeastward convergence between the two formations amounting to about 200 feet in a half-mile. In the absence of interfingering in the area, this feature is suggestive of a post-Mint Canyon pre-"Modelo" southwestward tilting and a subsequent erosion interval.

4. As pointed out by Clements,[21] the Mint Canyon formation does thin to the northwest. This thinning, however, is accomplished by the loss of *basal* members, probably because of an approach to a landward margin of the Mint Canyon basin of deposition. It appears likely that any marine interfingering in which the Mint Canyon has a part is to be found toward the *west* and *southwest*, not toward the northwest.

On the basis of invertebrates determined by Clark [22] and Woodring [23] as *Amphyssa* sp., *Ostrea titan*, *Pecten crassicardo*, *Pecten raymondi*, and *Astrodapsis* cf. *tumidus*, an upper Miocene age was assigned to the "Modelo." An invertebrate collection subsequently made by Maxson and identified by U. S. Grant IV [24] substantiates this age determination and justifies a more specific correlation with the uppermost Miocene Neroly. In addition to the forms given above, those determined by Grant include:

Terebratalia occidentalis
Terebratalia occidentalis obsoleta
Anadara osmonti
Anadara obispoana
Aequipecten discus
Lyropecten crassicardo
Lyropecten cf. estrellanus
Astrea aff. ? brangulata
Polinices sp.
Tegula sp.

Rather meager foraminiferal evidence reported by Hughes [25] further strengthens a Neroly age assignment. Thus, the Mint Canyon vertebrate horizons are older than the uppermost Miocene of the Pacific coast marine sequence.

Saugus Formation

The Saugus formation rests unconformably on the "Modelo" and Mint Canyon strata, and represents extensive deposition on a broad, westward-dipping floodplain or alluvial-fan series. Its beds are light gray to reddish

[21] T. Clements, *loc. cit.*, 1937.

[22] W. S. W. Kew, *op. cit.*, pp. 68–69, 1924.

[23] W. P. Woodring, "Age of the Modelo formation of the Santa Monica Mountains, California" (abstract), 28th Ann. Meeting, Cordilleran Section, Geol. Soc. Amer., Stanford University, California, 1929.

[24] J. H. Maxson, from paper entitled "Miocene-Pliocene boundary," 15th Ann. Meeting, Pacific Section, Amer. Assoc. Petrol. Geol., Los Angeles, California, November 3, 1938.

[25] R. M. Kleinpell, Miocene stratigraphy of California, p. 71. Amer. Assoc. Petrol. Geol., 1938.

brown, crudely stratified, and poorly consolidated. Mainly unsorted sands and conglomerates, they reflect the nature of the terranes from which they were derived. Fragments of the basement complex are most common, but silicic and intermediate volcanics are far from rare. Occasionally a mass of "Modelo" or Mint Canyon sandstone appears. Although these continental beds are generally nonfossiliferous, their marine analogues to the west yield invertebrates of late Pliocene and early Pleistocene affinities.

Quaternary Deposits

Terrace deposits of Pleistocene age are not uncommon, especially on the north side of Bouquet Canyon and in an ill-defined zone peripheral to the exposed basement complex between Vasquez and Mint Canyons. These rather flat-lying deposits consist of angular, unsorted gravelly material, commonly rich in fragments of schist, granitic rocks, and other types characteristic of the basement complex. Derivation from the latter under flood-plain conditions seems certain in this part of the basin. Although their typical form is locally obscured by later stream dissection, the terrace deposits are easily recognized by their predominant reddish-brown color, rather flat-lying attitude, and limited thickness. Although individual terraces (as they now occur) may have been formed at slightly different times, they all are Pleistocene in age.

More recently deposited alluvium forms broad flats in all the larger canyons and extends up the smaller ones as narrow tongues. It is generally made up of flat-lying sands and gravels of light gray color and varying degrees of coarseness, and is dissected to a limited extent by the present streams.

GEOLOGIC STRUCTURE

Evidences of crustal movements in the Mint Canyon area are widespread and well defined. No attempt has been made to interpret the intricate structural features found in the basement complex, but of post-Cretaceous orogeny a fairly clear picture can be obtained. In addition to the post-"Modelo" and post-Saugus periods of deformation characteristic of southern California, there is evidence of extensive faulting in the early Tertiary (late Eocene?), folding and faulting in post-Vasquez, pre-Mint Canyon time, and folding following deposition of the Mint Canyon formation. The early Tertiary structures seem to reflect tensional forces, and those of later age compression and shear; exceptions, however, are not uncommon.

In spite of the intense compressional forces indicated by certain of the faults, nearly all the folds are broad and open. The very competent Vasquez strata are little folded except in upper Tick Canyon, where the finer, softer beds which appear in the uppermost part of the section attain dips of 80° or more. Those of the Mint Canyon series, on the other hand, have been thrown into a great number of subdued flexures of prevailing east-west trend and shallow westward plunge (see fig. 5). North of Bouquet Canyon

is an area of more acute folding, the convolutions of two tuffaceous beds serving admirably as structural guides. Maximum dips are about 65°. Immediately to the southwest the "Modelo" is broadly folded with the usual east-west trend. Post-Modelo strata retain their original attitudes in the area mapped, but the Saugus is warped and folded a few miles to the south and west.

Faulting presents a more complex problem. Little is known of the early Tertiary faults, except that they presented sufficient vertical movement before and probably during at least a part of Vasquez deposition to demarcate a local basin deep enough to receive some 9000 feet of coarse sediments. In the region to the east, there is some evidence that these early faults were of the tensional block type, with dips of 65° or more. The close of Vasquez deposition ushered in a period of profound crustal movement, during which the older faults became active once more and new steeper fractures developed. Both normal and reverse movements occurred. The Vasquez-basement fault in Vasquez Canyon was a product of this orogenic period. Following the inception of Mint Canyon deposition, these faults experienced relatively little movement. The third period of faulting may be considered post-Mint Canyon, pre-Saugus, and resulted in fractures of northwest trend, steep dip, and dominantly strike-slip movement. In all cases, their northeast sides have moved north; they appear to have a gash fracture relation to the San Andreas rift, which lies several miles to the north. It is of interest that they cut and offset folds in the Mint Canyon formation wherever the two features occur in juxtaposition. That Pleistocene or even younger movements have occurred is evidenced by local offsets in the terrace deposits; such movements, however, have been of very slight extent.

AGE OF DEPOSITS

Tick Canyon Formation

The mammalian assemblage obtained from the Tick Canyon beds furnishes an independent means of reaching an age assignment. Inasmuch as a detailed discussion of the faunal relations appears elsewhere in this paper, it suffices at this point to note a similarity in stage of evolution between the species from the Tick Canyon and those from the lower Hawthorn formation of Florida and from the upper Harrison and upper Rosebud formations of Nebraska and South Dakota. A comparison with these faunas, as well as with others, presents evidence strongly favoring a late lower Miocene or earliest middle Miocene age. The Tick Canyon formation is thus placed in a position stratigraphically below that of the Merychippus zone at Coalinga and slightly below that of the Phillips Ranch horizon. Its marine time equivalent is probably the lower part of the Temblor as that term is broadly used, and upper-middle Temblor of the type section (see fig. 7).

Vasquez Series

The presence of a lower Miocene horizon unconformably above the Vasquez series introduces a feature not in accord with certain age assignments made for the latter series in the past. Although Kew [26] proposed an Oligocene (?) age, middle Miocene has been advocated by other investigators, notably W. J. Miller [27] and Simpson.[28] The arguments advanced to support this contention are:

1. The lavas interbedded with the Vasquez strata are typical of those extruded over broad areas in the western United States during the middle Miocene.
2. A strong resemblance exists between the Vasquez and the middle Miocene Topanga formation, not only in the associated volcanics, but in thickness and lithology.
3. The Vasquez seems to be a correlative of the middle Miocene Rosamond formation of the Mojave region.

The relation of the Vasquez to the lower Miocene Tick Canyon formation should constitute compelling enough evidence against a middle Miocene age determination for the former. Moreover, the writer feels that none of the above arguments furnishes evidence sufficiently strong to stand in the face of paleontologic data, indirectly applied though they may be. Granting a preponderance of volcanic activity during the middle Miocene, a possibility of earlier activity is not thereby precluded, particularly since such instances have been recorded.[29] Furthermore, the lavas of the Vasquez are mineralogically different from all others known from Los Angeles County,[30] a feature which is particularly noticeable in a comparison with the Rosamond formation. Finally, any correlation with the Topanga, no matter how tentative, is subject to serious error. The Topanga is marine and the Vasquez continental, so that a correspondence in total thickness or lithology is probably coincidental. The origin of the Vasquez as a fluviatile accumulation in a highly localized basin invalidates most correlations based on lithologic character, thickness, or probable prevailing climatic conditions.

The Vasquez is unconformably underlain by the lower Eocene Martinez formation in the Tejon Quadrangle to the west. The age possibilities are thus restricted to lower Miocene, Oligocene, and upper Eocene, essentially the age range of the Sespe. Although the Vasquez beds may never have been directly connected with the whole or any part of the Sespe, they probably were laid down in a somewhat similar topographic environment during a period corresponding to at least a part of the Sespe. An Oligocene age is tentatively assigned to the series, pending the discovery of fossil remains,

[26] W. S. W. Kew, U. S. Geol. Surv. Bull. 753, pp. 38–39, 1924.
[27] W. J. Miller, Univ. Calif. at Los Angeles Publ., vol. 1, 1934.
[28] E. C. Simpson, Calif. Jour. Mines and Geol., vol. 30, pp. 391–395, 1934.
[29] R. D. Reed, Bull. Amer. Assoc. Petrol. Geol., vol. 21, pp. 549–559, 1937.
[30] Y. Bonillas, personal communication.

although the associated flows suggest a time range extending into the lower Miocene.

Mint Canyon Formation

Because of previous discussions by Maxson,[31] Stirton,[32] and others, the fauna of the Mint Canyon formation need not be examined in detail at this time. Aside from disagreements on the exact nature of certain forms, the principal contentions appear to relate to the presence of *Hipparion*, Maxson favoring the theory of the appearance of the genus in the Miocene and Stirton holding the view that it is confined to the Pliocene. The question of utilization of *Hipparion* as a criterion of Pliocene age for the beds in which it occurs is one of world-wide application, and has brought forth discussion in Europe and Asia as well as in America. This genus has served as a basis for transoceanic correlation because of its wide and rapid dispersal from a probable American source. In this respect, its presence should be accepted as furnishing a more conclusive criterion than that of any late Tertiary invertebrate genus.

Because of the incompleteness of the original European section of the Tertiary as defined by Lyell and Deshayes, the critical Pontian and Sarmatian stages and their faunas were not included in the succession. Disagreement has subsequently arisen among European paleontologists with regard to the exact position of the Miocene-Pliocene boundary, as well as with regard to the relations of the invertebrate and vertebrate fossils employed in determining this boundary.[33] At present there is no unity of opinion as to the exact age of the type *Hipparion*-yielding strata. Nor are the stratigraphic relations of the beds containing *Hipparion* always clear. For Europe, then, the question is still unsettled.

Although at least the upper part of the Mint Canyon formation admittedly yields a fauna of undeniably lower Pliocene affinities (based on standards established by some vertebrate paleontologists), the bulk of the available evidence seems to favor a sensibly older assignment. The concept of a strict *Hipparion*-Pliocene affinity, together with the clear-cut unconformity between the Mint Canyon and overlying uppermost Miocene marine "Modelo," furnishes a striking example of the peculiar situation recognized by Reed and Hollister,[34] in which "the Lower Pliocene of most vertebrate paleontologists is at least in part the equivalent of the Upper Miocene of the invertebrate paleontologists." The confusion resulting from such conflict of views can be eliminated only by a change in age standards of either

[31] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, 1930.

[32] R. A. Stirton, Amer. Jour. Sci., 5th ser., vol. 26, pp. 569–576, 1933.

[33] G. H. R. von Koenigswald, Zentralbl. f. Mineral., pt. B, pp. 42–48, 1931. E. Stolley, Zentralbl. f. Mineral., pt. B, pp. 191–207, 1938. E. Stromer, Bayer. Akad. d. Wiss., Math.-naturwiss. Abt., vol. 32, pp. 1–20, 1938. H. Tobien, Deut. geol. Gesellsch. Ztschr., vol. 90, pp. 177–192, 1938.

[34] R. D. Reed and J. S. Hollister, Structural evolution of southern California, pp. 1586–1588. Amer. Assoc. Petrol. Geol., 1936.

vertebrate or invertebrate paleontologists, at least in that part of the geologic column near the Miocene-Pliocene boundary.

Because of the present state of disagreement with regard to the European section, disagreement in vertebrate correlations based on the genus *Hipparion*, and the clearly recognizable marine-nonmarine stratigraphic relations in the Mint Canyon area, the age determination of the Mint Canyon formation is here based on the invertebrate time scale of California, and the formation is therefore considered to be upper Miocene. This places the beds in a Tertiary marine succession whose record is essentially complete (as opposed to the fragmentary continental record and to the incomplete European marine record) and whose period boundaries commonly correspond to epeirogenic boundaries in the Pacific coast province. *Hipparion* remains thus occur stratigraphically below a Neroly marine fauna, with an appreciable sedimentary break between the two.

An apparent faunal gradation appears within the Mint Canyon formation, as shown by detailed mapping. *Hipparion* is found in the upper two-thirds of the section, and seems to give way to a merychippine fauna in the lowermost strata (see fig. 5). An intermediate protohippine fauna may exist, but disagreement exists concerning the forms. There is an indication, however, that a considerable time range is represented by the deposition, although even the lowermost beds may be post-Barstow in age.

The marine equivalent of the Mint Canyon formation is not found in the Ventura Basin east of the San Gabriel fault, in which area only Neroly marine strata are exposed. West of the fault, in the type section of the Modelo, the Modelo formation (restricted) of Hudson and Craig [35] is probably in part the equivalent of the Mint Canyon (see fig. 7). The unconformity noted by these investigators between the restricted Modelo and deposits which they call Santa Margarita may correspond to the Mint Canyon–"Modelo" unconformity of the Bouquet Canyon–Haskell Canyon area.

GEOLOGIC HISTORY

The geologic history of the Mint Canyon region has been touched upon in the discussion of various aspects of the present study. A brief review, therefore, should suffice to bring all the structural and lithologic data into a coherent sequence. The following events, in chronological order, are postulated for Tertiary and Quaternary time:

1. Early Tertiary (perhaps late Eocene) faulting, with attendant formation of an elongated topographic basin bordered for the most part by igneous terranes.
2. Oligocene and possibly early Miocene deposition of poorly sorted, coarse fanglomerates, sandstones, and silty beds in the basin, which was gradually subsiding.

[35] F. S. Hudson and E. K. Craig, Bull. Amer. Assoc. Petrol. Geol., vol. 13, pp. 509–518, 1929.

3. Extravasation of many flows and shallow intrusions of andesite and basalt during most of the period of accumulation of the thick Vasquez series.
4. Strong early Miocene faulting and subsidiary folding, in many cases along earlier zones of movement, elevating the Vasquez beds to a topographic position sufficiently high to induce active erosion.
5. Late lower Miocene deposition of the Tick Canyon strata, apparently in alluvial fans (fronting the steeper slopes), floodplains, and local lakes, with concomitant volcanism as evidenced by the presence of tuffaceous beds.
6. Early middle Miocene cessation of deposition, accompanied perhaps by uplift and minor folding.
7. Deposition of the Mint Canyon strata, both as coarse fluviatile and as fine lacustrine sediment; volcanism in adjacent areas is demonstrated by several lacustrine tuffaceous beds.
8. Late Miocene uplift and moderate erosion, concurrent with small-scale orogenic movements.
9. Invasion by marine waters from the west and deposition in them of the uppermost Miocene "Modelo" sandstones and shales.
10. Recession of the marine waters, post-"Modelo" folding, and at a slightly later time strike-slip faulting.
11. Pliocene and early Pleistocene development of broad, open plains receiving coarse sediment from adjacent dominantly granitic highlands.
12. Minor folding and warping.
13. Pleistocene terrace formation in much the same manner as in 11 above.
14. Uplift and dissection of terrace deposits.
15. Recent alluviation and minor uplifts.

FAUNA OF THE TICK CANYON FORMATION

Occurrence and Preservation of Material

Fossils are very sparsely distributed in the Tick Canyon strata. Only four localities yielding more than splinters of bone have been reported since collecting first began. Previously described material was obtained from thin fault slices of the Tick Canyon formation near the Mint Canyon narrows, but the material described in the following pages was collected from a large exposure near the head of Vasquez Canyon (*Bt* on the geologic map, fig. 4). The fossiliferous beds are reddish-brown sandy siltstones, occurring about 360 feet stratigraphically below the base of the Mint Canyon formation. Though chalky and very fragile, the remains themselves are well preserved. The occurrence, in which fairly complete skulls, dental series, and limb bones are found, is in striking contrast to that in the younger Mint Canyon strata, where remains are very fragmentary. None of the bones seems to have suffered from abrasion. Apparently the conditions of burial were favorable to the preservation of several individuals within a

small area, for many skeletal parts were found in close association. These features suggest a death from some catastrophe with immediate and rapid burial.

List of Species

The following faunal list comprises the forms definitely recorded from the Tick Canyon formation:

Rodentia:
  Heteromyid, prob. n. gen. and sp.
  Archaeolagus (?) sp.
Perissodactyla:
  Parahippus maxsoni, n. sp.
Artiodactyla:
  Merychyus calaminthus, n. sp.
  Miolabis californicus Maxson

Faunal Environment

Geologic observations furnish evidence of the existence of an adjacent mountain mass to the northwest during Tick Canyon time. The rather rapid progression from conglomeratic strata to fine-grained siltstones and clays further suggests a fairly flat-lying area of deposition at the base of this mountain mass. Certain strata noted in the section signify the presence of lakes; these were not of the playa type, but probably attained considerable depths. It is not surprising that these postulated conditions, which favor not inconsiderable local variations in environment, are in agreement with the evidence presented by the mammalian forms.

The pocket mouse is not particularly diagnostic so far as environment is concerned, in view of the present wide distribution of related forms under varying climatic conditions. The lagomorph, on the other hand, is suggestive, though not necessarily indicative, of a plains environment. *Parahippus*, with its short-crowned grinding teeth, was probably a browsing type, favoring wooded areas rather than an open, grassy terrane. *Merychyus* and *Miolabis* may have been plains-dwellers, although wooded areas near bodies of water probably attracted them. An analysis of the fauna as a whole, when combined with available geologic data, lends support to the view that the environment was that of a broad grassy plain, moderately and perhaps irregularly wooded, with a higher mountain mass lying immediately to the northeast. The climate was probably mild, with a rainfall greater than that which characterizes the region today.

Evolutionary Stage of Fauna

The various mammals of the Tick Canyon fauna present a homogeneous picture so far as stage of advance, as indicated by the phylogenetic development of individual types, is concerned. On the basis of recognized age determinations of North American Tertiary mammal horizons occupying an equivalent position in the evolutionary sequence, the Tick Canyon forms

may be regarded as late lower Miocene or possibly earliest middle Miocene in age. In spite of the prevalence of new species, the fossil material is well enough preserved to afford an evaluation of those characters most necessary for determination of the stage of evolution represented. The rodents indicate a stage presumably rather low in the Miocene. The equid material exhibits characters most commonly found in forms known from the lower Miocene. The well-preserved merycoidodonts resemble most closely Great Plains species from the upper Harrison and upper Rosebud, and the camelid is typically more primitive than allied forms from the middle Miocene.

Faunal Relationships

Comparative lists of mammalian species from the Tick Canyon, lower Hawthorn of Florida, and upper Harrison of Nebraska appear below. The latter two horizons are chosen because they most closely approximate the position of the Tick Canyon fauna in the Tertiary vertebrate sequence (see fig. 7). No direct comparison of the Rodentia is possible, but the Equidae and Merycoidodontidae are closely related. Although the camelid forms listed from horizons occurring beyond the Californian area are of the giraffe-camel line, they nevertheless show evolutionary characters corresponding to those of *Miolabis californicus.*

Comparative faunal lists

Tick Canyon	Lower Hawthorn	Upper Harrison
Rodentia:	Rodentia	Rodentia:
Heteromyid, prob. n. gen. and sp		Indet. sp.
Archaeolagus (?) sp.		
Perissodactyla:	Perissodactyla:	Perissodactyla:
Parahippus maxsoni, n. sp.	Archeohippus nanus	Parahippus coloradensis praecurrens
	Parahippus leonensis	Parahippus nebrascensis
		Parahippus n. primus
		Parahippus wyomingensis
		Parahippus pawniensis atavus
Artiodactyla:	Artiodactyla:	Artiodactyla:
Merychyus calaminthus, n. sp.		Merycochoerus magnus
		Merychyus arenarum minimus
		Merychyus a. leptorhynchus
Miolabis californicus	Oxydactylus floridanus	Oxydactylus longipes
		Oxydactylus brachyceps
		Procamelus (?) sp.

Pacific coast. The Tick Canyon is the only horizon of the Pacific coast province in which *Parahippus* appears to be the characteristic type of horse. The Merychippus zone at Coalinga [36] and the Caliente horizon,[37] in which *Parahippus* is found, are characterized by several merychippine types. Even the Phillips Ranch horizon,[38] occupying a position in the stratigraphic

[36] F. D. Bode, Carnegie Inst. Wash. Pub. No. 453, paper VI, p. 70, 1935.
[37] J. F. Dougherty, Carnegie Inst. Wash. Pub. No. 514, paper VIII, p. 115, 1940.
[38] J. P. Buwalda, Univ. Calif. Publ., Bull. Dept. Geol., vol. 10, pp. 75–85, 1916.

column slightly in advance of the Tick Canyon, yields a primitive *Merychippus*. The species of *Parahippus* occurring in the Caliente fauna appears to be a much more advanced form than *P. maxsoni*. The Coalinga anchitheriine, *P. brevidens*, exhibits a similar relation. Among the oreodonts, *Merychyus calimontanus* from the Caliente is a larger and more advanced form than *M. calaminthus*.

A large gap appears in the column below the Tick Canyon, the horizons nearest in age being the lower Miocene upper Sespe [39] and the lower Miocene or upper Oligocene Tecuya.[40] The only comparable forms from these horizons are oreodonts of much more primitive character than *M. calaminthus*.

Great Basin. The Tertiary vertebrate horizons of the Great Basin most nearly related to the Tick Canyon are the Virgin Valley,[41] Skull Spring,[42] and Mascall.[43] *Parahippus brevidens* and *P. avus* from the latter are advanced forms, as is *P.* near *coloradensis* from the Skull Spring horizon. This indication of later age is further borne out by the presence of merychippine forms in the Nevada and Oregon faunas. The merycoidodonts in these assemblages are generically distinct and thus preclude direct comparison, but they exhibit characters generally considered to be more advanced than those of the Tick Canyon form. The only camelid comparable to *Miolabis californicus* is *M. transmontanus* from the Mascall, a species whose characters are distinctly more advanced than those of the former. When comparisons are made with the upper John Day, the great faunal disparity is demonstrated by the presence in that formation of *Mesohippus*, *Eporeodon*, and *Paratylopus*, types that are much more primitive than comparable forms known from the California horizon.

Great Plains. The similarity of the upper Harrison faunas [44] to that from Tick Canyon, as based on the comparisons of *Parahippus*, *Merychyus*, and the long-limbed camels, has been noted. *Merychyus delicatus* from the upper Rosebud [45] most closely approaches *M. calaminthus* from the Tick Canyon; the equid and camelid forms from these two horizons likewise show similarities. The Sheep Creek horizon [46] presents a fauna slightly more advanced, but forms comparable to those from Tick Canyon are present. *Parahippus cognatus*, *Merychyus* sp., and *Miolabis tenuis* are larger and more advanced than *P. maxsoni*, *M. calaminthus*, and *M. californicus*, respectively. Presence in the fauna of *Merychippus insignis primus* is also indicative of a later stage. The lower Rosebud horizon is earlier in the

[39] C. Stock, Carnegie Inst. Wash. Pub. No. 404, paper III, pp. 31–36, 1930.

[40] C. Stock, Univ. Calif. Publ., Bull. Dept. Geol., vol. 12, pp. 267–276, 1920; Carnegie Inst. Wash. Pub. No. 418, paper IV, p. 89, 1932.

[41] J. C. Merriam, Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, pp. 204–209, 1911.

[42] C. L. Gazin, Carnegie Inst. Wash. Pub. No. 418, paper III, pp. 42–48, 1932.

[43] J. C. Merriam and W. J. Sinclair, Univ. Calif. Publ., Bull. Dept. Geol., vol. 5, pp. 195–197, 1907.

[44] O. A. Peterson, Ann. Carnegie Mus., vol. 4, pp. 56–72, 1906.

[45] F. B. Loomis, Bull. Amer. Mus. Nat. Hist., vol. 51, pp. 31, 33–34, 1924.

[46] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 65–73, 1924.

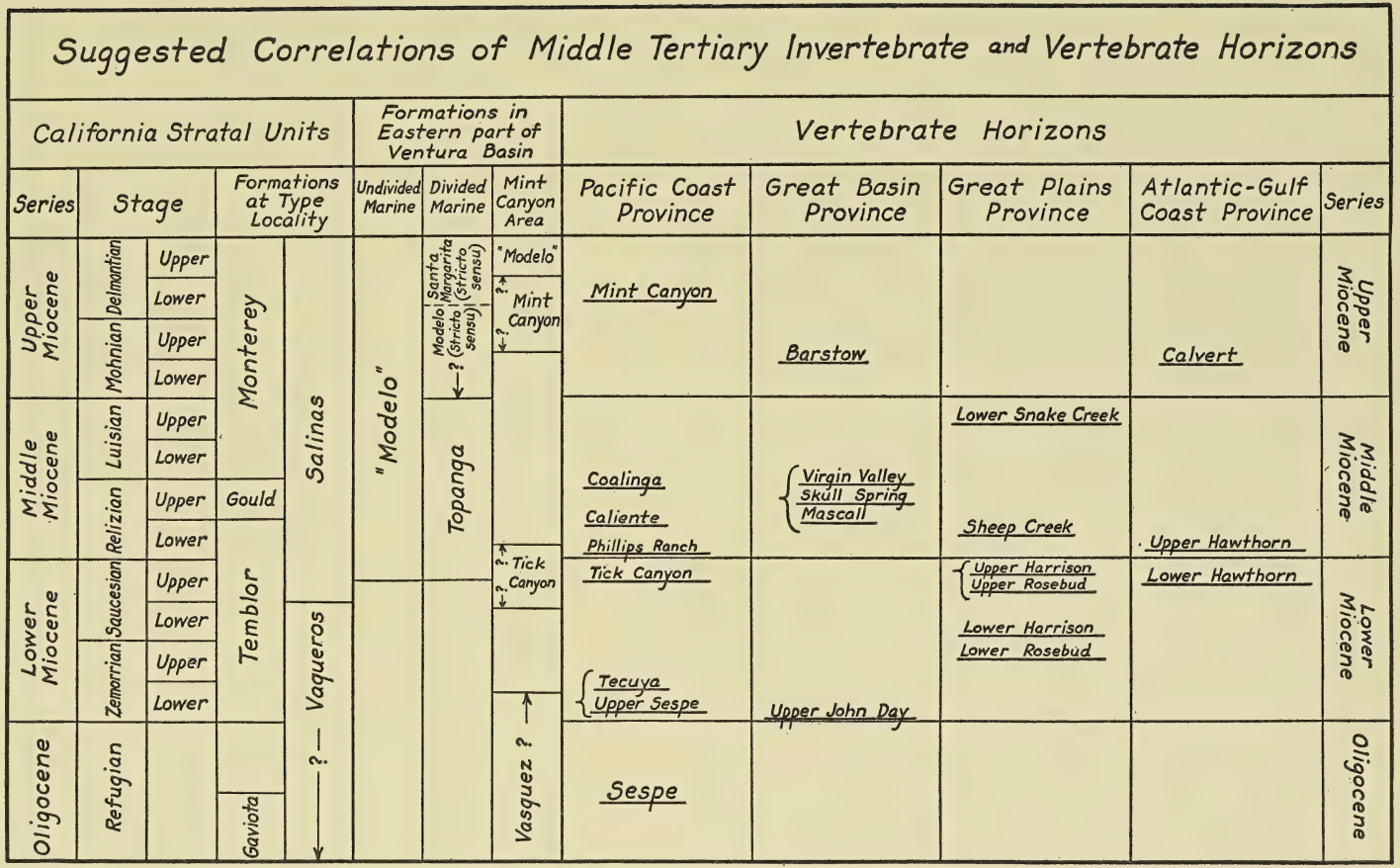


FIG. 7. Correlation chart showing time relations of middle Tertiary invertebrate and vertebrate horizons. Note position of the Mint Canyon and Tick Canyon faunas.

Miocene, so much so that it has been correlated with the upper Sespe.[47] The lower Harrison is also earlier, but apparently does not range quite so far down in the lower Miocene as does the lower Rosebud.

Atlantic-Gulf coast. The only mammal-bearing horizons in this province comparable to the Tick Canyon are the upper and lower Hawthorn of Florida.[48] That the lower Hawthorn is closely related to the California horizon, in spite of a paucity of comparable forms, has been pointed out. The upper Hawthorn differs from the Tick Canyon in yielding a primitive *Merychippus*, but lacks the presence of other forms on which a correlation might be established; it may be considered as approximately of same age as the Phillips Ranch horizon of the Pacific coast province.

Correlation. The upper lower Miocene position of the Tick Canyon formation, approximately equivalent to that of the upper Rosebud, upper Harrison, and lower Hawthorn, as well as its suggested marine analogues, is indicated in figure 7. Certain revisions in the section dealing with vertebrate horizons suggested by recent work in the Caliente Mountains have been the result of discussions with J. F. Dougherty. The section on California stratal units is taken from Kleinpell [49] and the division of the Modelo formation is the work of Hudson and Craig.[50] The following lists of certain Tertiary perissodactyls and artiodactyls are furnished for purposes of comparison not only with the Tick Canyon, but with the overlying Mint Canyon, thus demonstrating the faunal gap between the two.

DESCRIPTION OF SPECIES

Rodentia

Dr. Robert W. Wilson, who contemplates a detailed study of the Tick Canyon rodents and lagomorphs, has kindly supplied the following preliminary statement concerning the several forms involved:

The small mammal specimens obtained from quarry 201 comprise two incomplete skulls and five rami of a heteromyid rodent possibly representing a new genus, and two maxillae and three rami of a lagomorph, *Archaeolagus* (?).

The heteromyid genus has a premolar pattern typical of the perognathine division of the family, and except for the absence of grooves in the upper incisors is comparable superficially to the genus *Perognathus*. Characters in addition to the smooth incisors which may be noted are: (1) $P\underline{4}$ with single-cusped protoloph; union with metaloph delayed but median or slightly lingual; (2) palate between premolars slightly ridged; (3) $P\underline{4}$ relatively small, four-cusped; metalophid and protolophid well separated but uniting to form X pattern (protolophid joins metalophid via anteroexternal cusp); (4) weak H pattern in lower molars; some development of Y-shaped anterior crest but stylid not anterior in position; (5) cusps of cheek teeth apparently

[47] C. Stock, Carnegie Inst. Wash. Pub. No. 404, paper III, pp. 31–34, 1930.

[48] G. G. Simpson, Florida Geol. Surv., Bull. 10, pp. 11–16, 1932.

[49] R. M. Kleinpell, Miocene stratigraphy of California, fig. 14. Amer. Assoc. Petrol. Geol., 1938.

[50] F. J. Hudson and E. K. Craig, Bull. Amer. Assoc. Petrol. Geol., vol. 13, pp. 509–578, 1929.

Comparative perissodactyl-artiodactyl faunal lists of certain North American Tertiary horizons

1. Ricardo
2. Mint Canyon
3. Barstow
4. Lower Snake Creek
5. Coalinga
6. Skull Spring
7. Mascall
8. Caliente
9. Sheep Creek
10. Upper Hawthorn
11. Lower Hawthorn
12. Tick Canyon
13. Upper Rosebud
14. Upper Harrison
15. Upper John Day

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Perissodactyla:															
Pliohippus-Hipparion forms	×	×													
Protohippus-Merychippus forms		×	×												
Archeohippus mourningi			×		×										
Archeohippus ultimus							×								
Archeohippus penultimus									×						
Archeohippus cf. nanus										×					
Archeohippus nanus											×				
Merychippus (Protohippus) intermontanus		×?	×												
Merychippus calamarius stylodontus			×												
Merychippus sumani		×?	×												
Merychippus paniensis				×											
Merychippus proparvulus				×											
Merychippus campestris				×											
Merychippus eohipparion				×											
Merychippus sejunctus				×											
Merychippus brevidontus					×										
Merychippus californicus					×										
Merychippus isonesus						×	×								
Merychippus stevensi								×							
Merychippus severus							×								
Merychippus relictus							×								
Merychippus insignis							×								
Merychippus carrizoensis								×							
Merychippus insignis primus									×						
Merychippus gunteri										×					

(*Continued on following page*)

Comparative perissodactyl-artiodactyl faunal lists of certain North American Tertiary horizons—Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Perissodactyla—*continued*															
Parahippus integer				×											
Parahippus brevidens					×		×								
Parahippus near coloradensis						×									
Parahippus avus							×								
Parahippus sp.								×?							
Parahippus cognatus									×						
Parahippus leonensis											×				
Parahippus maxsoni, n. sp.												×			
Parahippus coloradensis praecurrens													×	×	
Parahippus nebrascensis														×	
Parahippus nebrascensis primus														×	
Parahippus wyomingensis														×	
Parahippus pawniensis atavus														×	
Mesohippus equiceps															×
Mesohippus acutidens															×
Mesohippus praestans															×
Artiodactyla:															
Metoreodon californicus	×														
Metoreodon relictus				×											
Merycochoerus buwaldi			×												
Merycochoerus sp.							×								
Merycochoerus magnus														×	
Merycochoerus matthewi													×		
Merycoidodont sp.							×	×		×					
Ticholeptus sp.						×		×?							
Pronomotherium siouense				×					×						
Merychyus sp.				×					×						
Merychyus calimontanus								×							
Merychyus calaminthus, n. sp.												×			
Merychyus delicatus													×		
Merychyus arenarum minimus														×	
Merychyus arenarum leptorhynchus														×	

Comparative perissodactyl-artiodactyl faunal lists of certain North American Tertiary horizons—Continued

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Artiodactyla—*continued*															
Eporeodon sp.															×
Eporeodon major longifrons															×
Promerycochoerus, several sp.															×
Alticamelus sp.		×	×		×?										
Alticamelus leptocolon				×											
Alticamelus procerus				×											
Alticamelus altus							×								
Alticamelus priscus									×						
Oxydactylus sp.					×?										
Oxydactylus floridanus											×				
Oxydactylus longipes													×	×	
Oxydactylus brachyceps														×	
Pliauchenia sp.			×												
Procamelus sp.			×		×								×?		
Protolabis angustidens				×					×						
Protolabis pusillus									×						
Protolabis saxeus									×						
Miolabis sp.					×?					×?			×		
Miolabis fissidens				×											
Miolabis transmontanus							×								
Miolabis tenuis									×						
Miolabis californicus												×			
Paratylopus cameloides															×

remain prominent for some time; (6) traces of posterior cingula in lower cheek teeth, anterior cingula in upper cheek teeth in some, at least, of the specimens; (7) $M\frac{3}{3}$ not noticeably reduced; (8) height of crowns moderate. The Mint Canyon heteromyid possesses an assemblage of characters which makes it difficult to allocate to any of the established genera. Structurally, it might be ancestral to either *Perognathoides* or *Cupidinimus*. Perhaps it is closer to the latter. No definite age determination can be made on the basis of the material at present, but a Miocene rather than Pliocene age is indicated.

The lagomorph remains apparently represent an advanced *Archaeolagus* or a very primitive *Hypolagus*. The Mint Canyon genus has a P2 with only one anterior inflection. P3 is very close to the comparable tooth in *Archaeolagus*. The upper molars have simple, short inflections without crenulations. These teeth lack the enamel crescents present, though not invariably, in the John Day *Archaeolagus*. Anterior and posterior columns of M3 are united by an isthmus of dentine of varying width, and none of the three specimens available exhibits the complete separation of the columns typical of *Hypolagus*. Cited characters indicate a form close to *Archaeolagus*, which in turn suggests a rather early Miocene age, but probably post-John Day, for the specimens. However, notes by L. R. Dice [51] on *Panolax* Cope indicate that forms of *Archaeolagus* type may have existed as late as the Santa Fe.

Perissodactyla

Parahippus maxsoni, n. sp.

(Plate 1, figure 1)

Holotype. C.I.T. No. 1385, palate of immature individual with well-preserved deciduous grinding teeth, a cervical vertebra, part of a humerus, shaft of fibula and tibia, incomplete manus and right pes.

Type locality. C.I.T. Vert. Pale. Loc. 201; west side of small canyon in the SW. corner of section 25, T. 5 N., R. 15 W., San Bernardino Base and Meridian, Humphreys Quadrangle, U. S. Geological Survey.

Geologic horizon. Tick Canyon formation, upper part of lower Miocene or lowermost middle Miocene.

Specific characters. Comparisons based on individual deciduous tooth measurements, as well as on the length of the deciduous premolar series, indicate a size greater than that of *Parahippus pristinus*,[52] but less than that of *P. cognatus* Leidy,[53] the genotype, and *Merychippus isonesus* (Cope).[54] The teeth are short-crowned, with a rather primitive pattern involving simple, straight, connected lophs, strongly developed cingulum below protoloph, and short, well-developed triangular hypostyle. A tiny crochet appears on the metaloph of Dp3 and Dp4. Cement is lacking, or present in negligible amount. The dentition resembles that of *P. pristinus*, but differs specifically in greater size, and in development of crochet, greater prominence of parastyle and mesostyle, and greater elongation of Dp2. The

[51] L. R. Dice, Jour. Mammal., vol. 4, no. 3, 1923.

[52] H. F. Osborn, Mem. Amer. Mus. Nat. Hist., vol. 2, pt. 1, pp. 76–77, pl. 25.1, 1918.

[53] Joseph Leidy, Proc. Acad. Nat. Sci. Phila., vol. 10, p. 26, 1858; Jour. Acad. Nat. Sci. Phila., vol. 7, p. 314, 1869.

[54] F. D. Bode, Carnegie Inst. Wash. Pub. No. 453, paper V, pl. 2, 1934.

metapodials and phalanges suggest an animal of rather light build. The pes is anisotridactylous.

The writer takes pleasure in naming this species for Dr. John H. Maxson.

Description

Dentition. The teeth are represented by a well-preserved set of deciduous cheek teeth. The narrowness of the space separating the right and left series may be due to a considerable crushing of the palate. The milk teeth are short-crowned, little worn, and very closely spaced. The length of the series, 61.6 mm., is compared with that of other forms in the table of measurements. The peglike first premolar is relatively large, elongated anteroposteriorly. Its crown is divided into two distinct basins, the posterior of which is much the smaller, roughly ovoid in shape, and shallow when compared with the crown height of the tooth. The large anterior basin is bounded externally by a strong, crescentic ridge, interiorly by a very low, narrow ridge. This tooth seems to have functioned, at least in part. The second premolar is the longest tooth present; it is markedly narrower than in *P. pristinus*, broader than in *M. isonesus*, but of nearly the same proportions as in *P. cognatus*. Although the transverse dimension of the remaining teeth increases to a maximum in Dp4, these teeth are relatively less broad than in most other species of the genus. The enamel surfaces are smooth, but local areas of slight rugosity do occur, chiefly on the interior faces of the lophs, on which appear tiny, irregular vertical striations. Local patches of a very thin calcareous scale, confined in general to the outer face of the ectoloph and to the inner surfaces of protocone and hypocone, may represent cement. The total amount present is very small. When the tooth row is viewed from the side, it presents a gently downward convex profile.

The protoloph, though sharply constricted and slightly bent between protocone and protoconule, is simple, continuous, and fairly straight. The bulbous, subconical protocone is larger than the protoconule, which is developed as a ridge-shaped swelling on the loph. The metaloph crest drops to a low saddle and follows a single tiny plication before joining the ectoloph. This union becomes progressively stronger from Dp2 to Dp4. The hypocone is symmetrically formed; from a point near its apex the metaloph slopes away in a nearly straight, continuous ridge, on which a metaconule is faintly indicated. An extremely small, thin, and bladelike crochet projects from the anterior side of the metaloph in Dp3 and Dp4, perhaps also in Dp2. This feature appears in the occlusal pattern only after much wear. Ptychoid crenulations and additional crochets are absent. The short hypostyle is strongly developed and triangular in cross section. It nearly encloses a small fossette, but opens externally in a sharp, V-shaped groove. By means of a low, narrow ridge it connects with the ectoloph, the most elevated part of the tooth. No pli-hypostyle is present.

A strong cingulum lies at the base of the protoloph; additional cingula are represented internally by the merest traces at the anterointernal base of the hypocone, externally by a slightly better defined bench at the base of the ectoloph. The external walls of the paracone and metacone are smooth, broken only by a low, narrow, rounded median rib. The para- and mesostyles are prominent, though rounded and narrow. A bladelike metastyle is distinct on Dp3 and Dp4, whereas on Dp2 the protostyle reaches prominence.

In its broad aspects the deciduous tooth pattern of the Tick Canyon specimen agrees with that of *Miohippus gemmarosae* Osborn,[55] an advanced form of the genus from the lower Rosebud formation, but differs in the union of metaloph and ectoloph, in the presence of a crochet, and in the shape of the individual teeth. Although the same differences in pattern persist, there is closer agreement in tooth shape and size with a species described by Douglass [56] as *Altippus taxus* and by Osborn [57] as *Parahippus taxus*, but later referred to the genus *Miohippus* by Schlaikjer.[58] From the dentition of *P. pristinus*, *P. maxsoni* differs in its larger size, presence of two basins in Dp1, superior development of the crochet, greater prominence of para- and mesostyles, and greater elongation of Dp2. Comparisons with the occlusal pattern of permanent dentitions furnish little of specific value, but lengths of premolar series are included in the table of measurements. In this respect, *P. maxsoni* is larger than *P. pristinus*, roughly comparable to *P. coloradensis praecurrens*, *P. pawniensis*, and *P. avus*, and distinctly smaller than *P. nebrascensis*, *P. nebrascensis primus*, *P. crenidens*, *P. tyleri*, and *P. wyomingensis*.

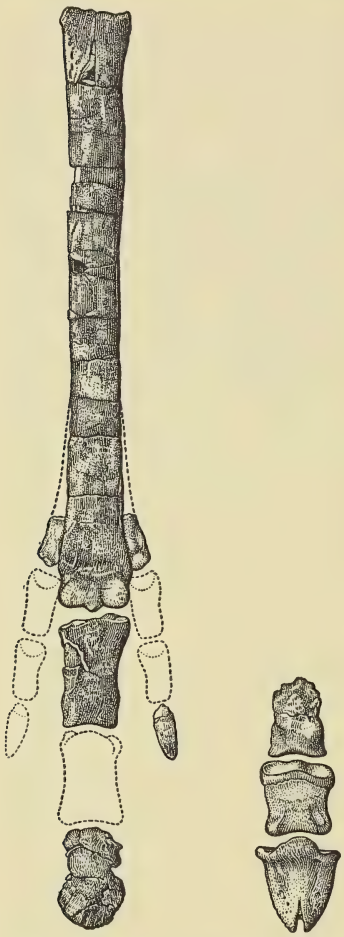


FIG. 8. *Parahippus maxsoni*, n. sp. Skeletal parts of feet, C.I.T. No. 1385, front view; ×½. Lower Miocene, Tick Canyon Formation, California.

Skeleton. The vertebral column is represented by one partially preserved third or fourth cervical. Although the neural spine is broken off, the specimen seems to have been of rather small size. The transverse process is wide and stubby. The zygapophyses are large, the prezygapophyses having a marked forward extent. The ventral keel is sharp and prominent. The neural canal is ovoid in section, with a moderate amount of flattening. The vertebrarterial canal is large and round.

The fore-limb bones are very fragmentary. The distal portion of a humerus bears a deep, elongated olecranon fossa, strongly developed epicondyle, and lateral condyloid crest. The only carpal bone present is a magnum, typically more flattened than in *Miohippus*. On the ventral surface are a strong, flat face and a small oblique facet for articulation with the third and second metacarpals, respectively. Articulating faces for scaphoid and lunar are represented by slight concavities on the dorsal surface,

[55] H. F. Osborn, *op. cit.*, pp. 66–68, 1918.
[56] E. Douglass, Ann. Carnegie Mus., vol. 4, pp. 271–273, 1908.
[57] H. F. Osborn, *op. cit.*, pp. 85–86, 1918.
[58] E. M. Schlaikjer, Bull. Mus. Comp. Zool., Harvard, vol. 80, p. 272, 1937.

from the rear of which rises a strong projection. The phalanges are in general like those of the hind foot, but are shorter and broader.

Portions of shafts of fibula and tibia denote a slender build; both are nearly circular in section throughout their middle extent, with a diametral ratio of approximately 1 : 4.5. A gently curving cnemial crest becomes very strong near the proximal end of the tibia. The only bone of the tarsus preserved is a cuboid. This element is large and extended anteroposteriorly. Although its proximal surface is transversely convex, it differs from that in *P. wyomingensis* in lacking an anteroposterior concavity on the rear portion. Additional articulating surfaces located on the distal side are an ovoid facet for metatarsal IV and a small oblique facet for metatarsal III; on the internal side, a faintly concave ovoid facet for the navicular. A large, bulbous tuberosity is present on the posterointernal corner of the distal surface. Remains of feet are shown in figure 8. Metapodial III is long and slender, with an expanded distal portion. A shallow, transversely elongated fossa lies on the dorsal surface of the distal portion, midway between the lateral tubercles. Both the rounded articulating surface and its keel are canted backward. The distal ends of metapodials II and IV show similar relations, but are much smaller and compressed transversely. The ungual phalanx is strongly notched at its distal end.

Discussion

Although the skeletal characters, so far as they are known, serve only to indicate an appreciable advance over *Miohippus*, the dentition of *P. maxsoni* is far more diagnostic. Comparisons with other deciduous dentitions seem to fix within reasonably small limits the stage of evolution of this species in the genus. That the Tick Canyon species represents a more advanced stage than does the lower Miocene *P. pristinus* and a slightly earlier stage than does the middle Miocene *P. cognatus* has been pointed out. The negligible amount of cement, very simple loph structure, and shape and size of the teeth denote rather primitive characters, even for a deciduous dentition. Inasmuch as both milk and permanent dentitions are known for *P. pristinus*, if we accept Schlaikjer's suggestion [59] that *P. cognatus* and *P. coloradensis praecurrens* (the latter represented by permanent teeth) are specifically identical, the opportunity presents itself to compare *P. maxsoni* with other members of the genus, at least so far as relative evolutionary development is concerned. It appears that the Californian species occupies a position in the evolutionary sequence of the Equidae corresponding to that of forms from the upper Harrison and upper Rosebud formations of the Great Plains province, or to that of the Merycochoerus-Parahippus zone of Osborn.[60] Further, it seems reasonable to refer to *P. maxsoni* the equid material previously collected from the same beds. This specimen was described by Maxson [61] as *Parahippus ?* (*Archeohippus*) near *mourningi* and later referred by Bode [62] and Stirton [63] to *Parahippus* sp. Bode notes at least one character which suggests that this fossil species belonged to an earlier stage than that to which it has been assigned (upper Miocene).

[59] *Ibid.*, pp. 275–276, 1937.
[60] H. F. Osborn, *op. cit.*, p. 79, 1918.
[61] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, pp. 91-92, 1930.
[62] F. D. Bode, Carnegie Inst. Wash. Pub. No. 440, paper V, pp. 55–56, 1933.
[63] R. A. Stirton, Amer. Jour. Sci., 5th ser., vol. 26, pp. 570–571, 1933.

*Comparative measurements (in millimeters) of deciduous dentitions**

1. *Parahippus maxsoni*, n. sp., C.I.T. No. 1385.
2. *Parahippus pristinus* Osborn, A.M. No. 12915.†
3. *Parahippus cognatus* Leidy, U.S.N.M. No. 567.‡
4. *Parahippus taxus* Douglass, Car. Mus. No. 836.† §
5. *Merychippus isonesus* (Cope), C.I.T. No. 544.‖

	1	2	3	4	5
Superior series, Dp1 to Dp4, length	61.6	54	..	59¶	..
Superior series, Dp2 to Dp4, length	55.5	46	67¶	50¶	65
Dp1, anteroposterior diameter	9.2	11	..	11	..
Dp1, transverse diameter	6.5	6	..	7	..
Dp1, crown height	8.1	**	..	**	..
Dp2, anteroposterior diameter	21.2	17	25	20¶	27
Dp2, transverse diameter	15.0	14	18	15	18
Dp2, crown height	11.1	**	..	**	11
Dp3, anteroposterior diameter	17.0	14	19	15	20
Dp3, transverse diameter	16.8	15	20	16	19
Dp3, crown height	12.5	**	..	**	13
Dp4, anteroposterior diameter	18.5	15	20	15	20
Dp4, transverse diameter	17.8	15	20	17	19
Dp4, crown height	13.6	**	..	**	12

* Anteroposterior diameter of Dp1 and Dp2 is the maximum diameter at the base of crown; otherwise the system of measurements is that of Bode (*op. cit.*, p. 46, 1933).
† H. F. Osborn, *op. cit.*, pp. 76–77, 85–86, 1918.
‡ Joseph Leidy, *op. cit.*, p. 314, pl. 21, 1869.
§ Referred to genus *Miohippus* by Schlaikjer.
‖ F. D. Bode, *op. cit.*, pl. 2, 1934.
¶ Approximate.
** Measurements not taken because of worn character of tooth.

*Comparison of permanent dentition of Parahippus maxsoni with those of other forms (measurements in millimeters)**

Species	Superior premolar series, P1 to P4	Superior premolar series, P2 to P4
Parahippus maxsoni (C.I.T. No. 1385)	61.6†	55.5†
Parahippus pristinus Osborn (A.M. No. 12918)	50	42
Parahippus tyleri Loomis (Amer. Coll. No. 1079)	65‡	59
Parahippus nebrascensis Peterson (Car. Mus. No. 1440)	72	66
Parahippus n. primus Osborn (A.M. No. 13770)	77	71
Parahippus coloradensis praecurrens Osborn (A.M. No. 13018)	..	54
Parahippus avus Marsh (Yale Mus. No. 11281)	61‡	57
Parahippus crenidens Scott (Prin. Mus. No. 10430)	68	58
Parahippus pawniensis Gidley (A.M. No. 9085)	59	51
Miohippus gemmarosae Osborn (A.M. No. 13808)	61	52
Parahippus wyomingensis Schlaikjer (M.C.Z. No. 6309)	65	59

* Measurements taken in part from Osborn.
† Deciduous dentition.
‡ Approximate.

Limb measurements (in millimeters)

	Parahippus maxsoni	*Parahippus wyomingensis* Schlaikjer*
Metatarsal III, maximum length	154.6	223.4
Metatarsal III, maximum width at proximal end	20.0†	30.2
Metatarsal III, maximum width at distal end	20.4	30.0
First phalanx of middle digit, pes, maximum length	30.4	42.8
Second phalanx of middle digit, manus, maximum length	20.7	28.1
Second phalanx of middle digit, pes, maximum length	25.0	29.7
Ungual phalanx, manus, middle digit, maximum length	23.1	34.8
Ungual phalanx, manus, middle digit, maximum width	21.3	....
Ungual phalanx, pes, middle digit, maximum length	24.6	40.7
Ungual phalanx, pes, middle digit, maximum width	20.0†	35.5

* E. M. Schlaikjer, *op. cit.*, pp. 270–271, 1937.
† Approximate.

*Measurements (in millimeters) and indices of the ungual phalanx, middle digit, of the pes**

Species	Length	Width	Index
Parahippus pristinus	26.0	19.0	0.730
Parahippus pawniensis atavus	33.0	26.0	.790
Parahippus maxsoni	24.6	20.0†	.81†
Parahippus avus	35.5	30.0	.845
Parahippus leonensis	28.0	24.0	.856
Parahippus tyleri	39.0	33.5	.859
Parahippus wyomingensis	40.7	35.5	.872
Parahippus coloradensis praecurrens	35.0	31.0	0.886

* Data on all species other than *P. maxsoni* taken from Schlaikjer.
† Approximate.

Artiodactyla

Merychyus calaminthus, n. sp.

(Plate 1, figures 2–3*a*; plates 2, 3)

Cotypes. C.I.T. No. 1383, incomplete skull of an adult animal with nearly perfect cheek-tooth series; C.I.T. No. 1342, poorly preserved adult mandible; C.I.T. No. 1382, middle and posterior part of skull with nearly complete molar series and well-preserved basicranial region; C.I.T. No. 1829, skull of an immature animal, complete anterior to cranium, lower jaws present, one in articulation with skull and one separated.

Paratypes. C.I.T. No. 1384, imperfect skull and lower jaws of a young individual; C.I.T. No. 2684, miscellaneous teeth; C.I.T. No. 2681, parts of left hind foot and tibia.

Type locality. C.I.T. Loc. 201; west side of small canyon in SW. corner of section 25, T. 5 N., R. 15 W., San Bernardino Base and Meridian, Humphreys Quadrangle, U. S. Geological Survey.

Geologic horizon. Tick Canyon formation, upper part of lower Miocene or lowermost middle Miocene.

Specific characters. The most mature specimens are slightly smaller than *Merychyus delicatus*, heretofore the smallest recorded species of the genus,[64] and notably smaller than *M. arenarum minimus*[65] and *M. curtus*.[66] The slender build is further indicated by the small eye socket, slender zygomata, and smallness of cranial region of the skull. The most diagnostic single character, however, is a pronounced ovoid antorbital fossa, at the anterior edge of which is a tiny facial vacuity. The dentition closely resembles that of *M. delicatus*, with uncrowded premolars and characteristic premolar pattern; the only notable character is a distinct spur projecting outward from the inner crescent of $P\underline{4}$.

Description

Skull. Although no complete skull is available, accurate composite measurements indicate a mesocephalic index of about 0.54. The dorsal surface, as shown in No. 1382, is low and flattened, with its highest point at the postorbital constriction. The brain case has a nearly circular horizontal cross section, and its upper surface is marked by two broad, very low temporal ridges. These ridges unite just in back of the glenoid fossae to form a short, narrow sagittal crest that is clearly defined but not prominent. The occipital crests are sharp and well developed.

[64] F. B. Loomis, Bull. Amer. Mus. Nat. Hist., vol. 51, art. 1, pp. 31, 33–34, fig. 22, 1924.
[65] O. A. Peterson, Ann. Carnegie Mus., vol. 4, pp. 56, 67–68, fig. 16, 1906.
[66] F. B. Loomis, *op. cit.*, pp. 31–33, figs. 19, 20, 1924.

The malar is of medium build, but the zygomatic arches are light. The elevated orbits are rather small and only slightly elongated anteroposteriorly. From the orbits, the lachrymals project forward to occupy a rather extensive area on the face; they are concave outward, forming pronounced, anteroposteriorly elongated antorbital fossae. At the front edges of these ovoid depressions are very small facial vacuities, bounded mainly by the maxillaries, in part by the lachrymals, and apparently to a small extent by the frontals. The short nasals are widest at their anterior ends. These elements appear to be slightly constricted at the middle, and are rounded posteriorly. The frontals, flat to gently convex, rise to a low ridge at the orbital rim. Although the relations are obscured to some extent by dorsoventral crushing, the palate appears to be gently vaulted and wide.

Both basioccipital and basisphenoid are narrow and strongly convex downward. The tympanic bullae are not preserved. Projection of the occiput over the foramen magnum is not great. The pterygoids are not fully preserved, but appear to have been thin; the vomer, on the other hand, is thick. The rather open glenoid fossae lie in a line normal to the basicranial axis, and are bounded posteriorly by sharply defined, downward-directed postglenoid processes. Although the paroccipital processes are broken off, they seem to have been sensibly smaller than the postglenoid processes.

Mandible. The inclination of the symphyseal border of the jaw makes an angle of 43° with the tooth row in the young individual, No. 1384; this angle is apparently increased in more mature animals. The symphysis is short and vertically slightly convex. The inferior edge of the mandible is straight, sloping gently backward and terminating in a poorly defined angle; the depth of the jaw at this point is considerably less than in other representatives of the genus. The coronoid process is short, thin, and rounded at its end. A broad and shallow sigmoid notch is bounded posteriorly by a slender condyle with very straight transverse surface. At its horizontal, clearly marked lower edge, the masseteric fossa is deep, but becomes shallower toward the coronoid process.

Foramina. In spite of local crushing, several foramina are clearly visible in the basicranial region. A large foramen ovale is situated internally with respect to the glenoid fossa, and a small, round foramen lacerum anterius is completely concealed in ventral view by a marked overhang of the pterygoid. There is no trace of a foramen rotundum, and an alisphenoid canal is not present; instead, the carotid artery appears to have been carried in a short, moderately narrow, but very deep groove. This groove is bounded exteriorly by a stubby pyramidal process situated on the posterior outer edge of the alisphenoid, and interiorly by one of the ventrally diverging pterygoids.

A portion of the rim of the foramen lacerum medium is preserved posterointernally to the foramen ovale, and there is a suggestion of an edge of a foramen lacerum posterius in back of the space occupied by the tympanic bulla.

The infraorbital foramina lie above the middle part of $P\underline{3}$, and the posterior palatine foramina occupy positions opposite $P\underline{4}$. The supraorbital foramina are only 5 mm. apart, and are situated immediately adjacent to the frontonasal suture. They open into shallow grooves which apparently extend directly forward. The mental foramen, the only one observable in the mandible, lies below the anterior end of $P\underline{3}$.

Dentition. The superior teeth are sub-hypsodont to hypsodont, and are closely spaced but not crowded. The incisors are small, with ovoid cross sections; the canines are pyramidal and moderately large. The molar-premolar rows are nearly straight both horizontally and vertically, although a tendency toward downward convexity is displayed in immature individuals. Except for a backward tilt in P1 and P2 and an oblique position for P1, the individual cheek teeth stand straight in the jaw. The molars, which overlap slightly, increase in length rapidly from M1 to M3. M2 resembles M1 more closely in size than it does M3. M1 is essentially square in outline, in which character this tooth differs from the posterior molars. This difference is due in part to differential wear. Shortening of the tooth row has taken place with reduction in size of the anterior parts of P1, P2, and P3 and with complete loss of the anterior end of P4.

The cheek teeth follow the typical *Merychyus* pattern, with the addition of certain minor characters. A small but distinct spur projects outward from the inner crescent of P4, but lies too far posterior to be a vestige of the median crest. The tiny pit (a remnant of the anterior basin) present at the anterior outer corner of P4 in *M. curtus* and *M. delicatus* is absent in *M. calaminthus*. Below the corners of the crescent are short cinguli; the anterior one is very sharp and trough-like. No distinct cingulum is present elsewhere in teeth of the upper dentition. In P3, which is shorter transversely than in *M. delicatus*, the posterior basin is obliquely elongated. The anteriorly convex anterior intermediate crest is sharper and more prominent than either of the adjacent crests or the anterior crescents. This crest has a greater extent in P2, and in the latter tooth that portion of the basin in front of the intermediate crest is vestigial or absent. Parastyle and mesostyle are inconspicuous in M1, but become increasingly prominent in M2 and M3. Moreover, M3 possesses a distinct metastyle.

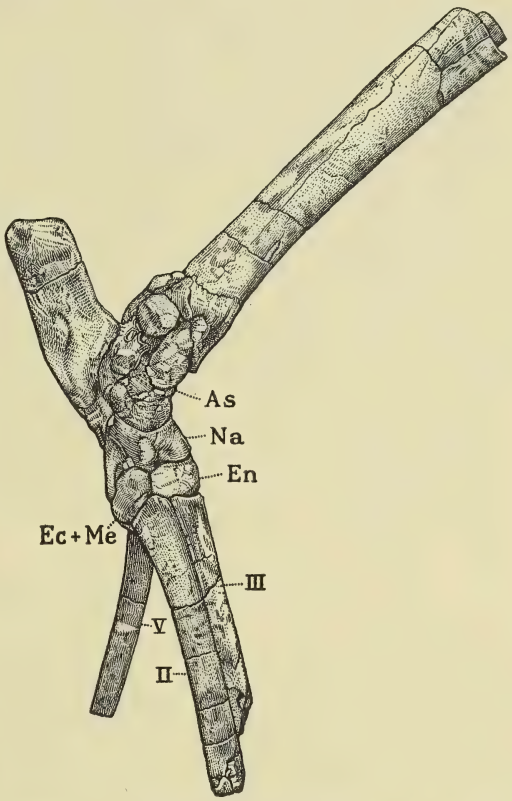


FIG. 9. *Merychyus calaminthus*, n. sp. Left pes with tibia, inner view; ×1. *As*, astragalus; *Na*, navicular; *En*, entocuneiform; *Ec & Me*, ecto- and mesocuneiform; II, III, V, metatarsals. Lower Miocene, Tick Canyon Formation, California.

The superior milk dentition is represented by poorly preserved premolars. The molariform Dp4 seems crowded into a nearly square outline; it contains two basins and bears a well-developed parastyle, mesostyle, and metastyle.

Dp$\underline{2}$ and Dp$\underline{3}$ are too imperfectly preserved to permit a clear picture of their occlusal patterns.

Because of the worn grinding surfaces of the inferior teeth, little of their pattern can be discerned. The premolars are crowded and partially overlapping, P$\bar{1}$ and P$\bar{2}$ lying transversely in the jaw. The strongly caniniform P$\bar{1}$, though short-rooted, is larger than the canine, which is also transverse. As in the superior dentition, M$\bar{3}$ is much larger than M$\bar{1}$ or M$\bar{2}$. Styles are strongly developed, especially on the molars. Straight, narrow internal cinguli appear on P$\bar{3}$ and P$\bar{4}$, which are further characterized by a very deep indentation of the external wall just forward of the posterior crest, with an attendant anterior narrowing of each tooth. The deciduous lower teeth show much the same characters as the corresponding permanent units, except for the molariform, three-basined Dp$\bar{4}$, whose well-defined crescents are separated by deep, narrow valleys extending only part way down the crown. Styles typical of the molars are also present on this tooth.

Skeleton. Among the best preserved of the skeletal remains is a left pes, with the distal parts of the tibia and a thin, slender fibula; all bones are in articulation (fig. 9). The phalanges are missing, and of the metatarsals only the second is reasonably complete. The estimated length from the end of metatarsal II to the posterior end of the calcaneum is 81 mm. The cuboid is rather elongated; the navicular shows a slender anterior projection on the under side of the foot; and the middle and external cuneiform bones are not fused. That the animal was of light build is indicated by the relative slenderness of all the foot bones, especially the metatarsals (for comparisons with *M. arenarum minimus*, see table of measurements). Other, more fragmentary and poorly preserved hind-limb elements have similar characteristics.

Discussion

Although the brain case is slightly wider than in *M. delicatus*, the smaller features of *M. calaminthus* are reflected by lighter zygomata, more restricted skull width between orbits, and smaller diameter of orbit. The skull in the Californian species is of nearly the same shape as in *M. arenarum minimus*, as is shown by comparison of cephalic indices, 0.54 and 0.55 respectively; that of *M. delicatus* is 0.62 (approximately). Differences in the dentition are seen in the molar-premolar ratios, 0.80 for *M. calaminthus* as compared with 0.83 for *Merycoidodon*, 0.84 for *Merychyus delicatus*, and 0.74 for *M. arenarum minimus*. In addition to the differences in occlusal pattern of the premolars that have been pointed out, it should be noted that complete internal cinguli, present in P$\underline{4}$ and M$\underline{3}$ of *M. delicatus*, are absent in the comparable teeth of the species from southern California.

Merychyus calaminthus is more primitive than most species of the genus, as is demonstrated by its cephalic index, small size, restricted facial vacuities, presence of an open groove which appears to represent a vestigial alisphenoid canal, lack of extensive shortening in P$\underline{2}$ and P$\underline{3}$, lack of strong backward cant to upper premolars, and the heavy styles in M$\underline{3}$. On the other hand, this form may represent a slight advance beyond *M. delicatus*, as is indicated perhaps by presence of a facial vacuity, slightly broader brain case, lower molar-premolar index (reflecting greater premolar shortening), and more complex premolar pattern. Additional comparisons can be made from the table of measurements.

Comparative measurements (in millimeters)

1. *Merychyus calaminthus*, n. sp., C.I.T. No. 1383.
2. *Merychyus calaminthus*, n. sp., C.I.T. No. 1342.
3. *Merychyus calaminthus*, n. sp., C.I.T. No. 1382.
4. *Merychyus calaminthus*, n. sp., C.I.T. No. 1829.
5. *Merychyus calaminthus*, n. sp., C.I.T. No. 1384.
6. *Merychyus delicatus* Loomis.*
7. *Merychyus arenarum minimus* Peterson.*
8. *Merychyus curtus* Loomis.*

Skull	1	3	4	5	6	7	8
Maximum length			126.0†	96.0‡	140‡	160.0	156
Basal length					130‡	148.0	148
Bizygomatic diameter	75.0‡	67.9	68.0		88‡	88.5‡	98
Postorbital constriction, diameter		36.0	35.0	33.0‡	34	34.5	32
Brain case, diameter		42.3	42.0‡	36.0‡	40‡	44.0	42
Width between middle of orbits	58.0	50.0	48.5	42.0‡	56	58.0	50
Orbits, anteroposterior diameter	21.5	20.0	18.8		24	22.0	25
Orbits, vertical diameter	20.0	16.2	14.7		20	24.0	24
Molar, depth below orbit	13.0	10.8	8.0		12	16.0	18
Bulla, anteroposterior diameter					16	19.6	22
Bulla, transverse diameter						14.0	18
Palate, width between P$\underline{1}$	20.5‡		16.5	12.8‡		19.6	21
Palate, width between M$\underline{3}$	25.0‡	23.0	22.0	16.5‡		24.6	28
Facial vacuity, maximum diameter			3.0‡			19.0	14
Facial vacuity, minimum diameter						10.0	3
Ramus, maximum length			82.0‡	91.0‡	110	129.0	122
Symphyseal length				20.0	27	32.0	25
Depth, coronoid to angle			50.0‡		71	73.0	76
Depth below M$\underline{3}$			20.0		28	28.0	27
Cephalic index			0.54		0.62‡	0.55	0.62

* Measurements taken in part from M. R. Thorpe, Mem. Peabody Mus. Nat. Hist., vol. 3, 1937.
† Composite value; measurements made on two specimens.
‡ Approximate.

Superior dentition	1	3	4	5	6	7	8
Superior dental series, C to M$\underline{3}$					74.0	77.0	70.0
Superior molar series	36.2	31.0	28.6	30.0‡	36.0	40.5	38.0
Superior premolar series	29.0				30.2	30.0	28.0
$\underline{C}$, anteroposterior diameter			5.4	3.4	4.0	7.3	4.0
$\underline{C}$, transverse diameter			4.4	2.5	4.0	6.7	6.0
P$\underline{1}$, anteroposterior diameter	6.9		6.0	6.5	7.3	7.1	6.3
P$\underline{1}$, transverse diameter	4.5		4.4	3.7	5.6	4.3	4.5
P$\underline{2}$, anteroposterior diameter	7.7				9.0	9.4	7.5
P$\underline{2}$, transverse diameter	6.5				7.5	7.0	5.8
P$\underline{3}$, anteroposterior diameter	8.1				8.0	9.2	7.5
P$\underline{3}$, transverse diameter	7.8				9.0	8.6	7.2
P$\underline{4}$, anteroposterior diameter	7.3				7.7	8.6	7.0
P$\underline{4}$, transverse diameter	9.2				10.9	10.4	9.0
M$\underline{1}$, anteroposterior diameter	10.7	8.6	10.2	8.7	9.7	12.3	12.0
M$\underline{1}$, transverse diameter	10.8	8.7	9.3	7.3	12.6	12.5	11.5
M$\underline{2}$, anteroposterior diameter	13.5	11.7	13.5	9.5	12.5	15.2	14.0
M$\underline{2}$, transverse diameter	11.9	11.5	10.8	8.7	14.1	14.1	13.0
M$\underline{3}$, anteroposterior diameter	15.7	14.2	13.9‡	12.0‡	16.4	18.6	15.0
M$\underline{3}$, transverse diameter	13.0	10.5	10.6	8.5‡	15.1	14.7	12.0
Molar-premolar index	0.80		0.80		0.84	0.74	0.74

‡ Approximate.

(*Continued on following page*)

Comparative measurements (in millimeters)—continued

Inferior dentition	2	4	5	6	7	8
Inferior molar series	36.0‡	.....	.....	39.0	43.0	42.0
Inferior premolar series	.....	.....	.....	29.0	30.0	33.0
$\overline{C}$, anteroposterior diameter	.....	.....	4.0	.....	4.5	2.0
$\overline{C}$, transverse diameter	.....	.....	3.1	.....	6.5	.....
$P\overline{1}$, anteroposterior diameter	4.3	6.6	4.7	.....	8.0	5.0
$P\overline{1}$, transverse diameter	4.7	5.2	2.5	.....	6.3	4.0
$P\overline{2}$, anteroposterior diameter	.....	.....	6.2	8.0	8.3	6.0
$P\overline{2}$, transverse diameter	.....	.....	3.0	4.0	5.3	3.0
$P\overline{3}$, anteroposterior diameter	7.2	.....	8.1	9.0	9.5	9.8
$P\overline{3}$, transverse diameter	5.3	.....	4.1	6.6	5.3	4.0
$P\overline{4}$, anteroposterior diameter	9.0	.....	.....	10.2	11.6	10.5
$P\overline{4}$, transverse diameter	6.0	.....	.....	8.0	7.0	5.2
$M\overline{1}$, anteroposterior diameter	8.4	9.5	10.4	10.1	10.7	9.7
$M\overline{1}$, transverse diameter	7.1	6.7	6.0	8.9	8.9	6.2
$M\overline{2}$, anteroposterior diameter	10.3	13.0	12.7‡	12.0	14.2	11.5
$M\overline{2}$, transverse diameter	7.3	7.5	7.5	10.2	9.5	6.5
$M\overline{3}$, anteroposterior diameter	17.4	12.0‡	.....	20.0	21.7	19.0
$M\overline{3}$, transverse diameter	8.2	7.0‡	.....	10.3	10.7	7.5

‡ Approximate.

Deciduous dentition	4	5
Superior deciduous series, length	23.0	....
$Dp\overline{2}$, anteroposterior diameter	6.2	....
$Dp\overline{2}$, transverse diameter	4.9	....
$Dp\overline{3}$, anteroposterior diameter	7.4	....
$Dp\overline{3}$, transverse diameter	7.1	....
$Dp\overline{4}$, anteroposterior diameter	7.8	....
$Dp\overline{4}$, transverse diameter	8.2	6.1
Inferior deciduous series, length	24.0	26.5
$Dp\overline{2}$, anteroposterior diameter	5.0	....
$Dp\overline{2}$, transverse diameter	3.6	....
$Dp\overline{3}$, anteroposterior diameter	6.9	....
$Dp\overline{3}$, transverse diameter	4.1	....
$Dp\overline{4}$, anteroposterior diameter	11.6	12.5
$Dp\overline{4}$, transverse diameter	5.8	5.4

Skeleton	C.I.T. No. 2681	*M. a. minimus*§
Length of left pes, calcaneum to distal end of metatarsal II	81.0 ‡	83.0
Calcaneum, length	34.8	35
Calcaneum, average depth	10	....
Calcaneum, average transverse diameter	7	....
Navicular, maximum depth	12.7	....
Astragalus, transverse diameter at distal pulley	11.6	12.2‡
Metatarsal II, length	41.0‡	42.0‡
Metatarsal II, dorsoventral diameter of shaft	3.8	....
Metatarsal II, transverse diameter of shaft	4.6	3.0
Metatarsal III, dorsoventral diameter of shaft	5.5‡	....
Metatarsal III, transverse diameter of shaft	6.5	7.0
Metatarsal IV, dorsoventral diameter of shaft	5.0‡	....
Metatarsal IV, transverse diameter of shaft	6.0‡	7.0
Metatarsal V, dorsoventral diameter of shaft	3.9	....
Metatarsal V, transverse diameter of shaft	3.7	4.0

‡ Approximate.
§ O. A. Peterson, Ann. Carnegie Mus., vol. 15, pp. 299–304, 1923.

Camelidae

(?) **Miolabis californicus** Maxson

Two lower teeth, C.I.T. Nos. 2682 and 2683, were obtained at C.I.T. Loc. 201. They represent a moderately worn fourth premolar and an unworn deciduous premolar of like position. Although the absence of a lower dentition in the type specimen precludes the possibility of direct comparison, these teeth are provisionally referred to *Miolabis californicus* Maxson.[67]

The size of the specimens presumably agrees with that of *M. californicus* as inferred from the upper dentition of the latter. $P\bar{4}$ is larger than in *Miolabis tenuis* Matthew [68] and roughly comparable to the corresponding tooth in *Oxydactylus floridanus* Simpson,[69] *O. longipes* Peterson,[70] and *Paratylopus cameloides* (Wortman).[71] Lack of mandibular material prevents comparison with *Miolabis transmontanus* (Cope), the genotype. Though typically compressed laterally, the tooth is broader, longer-crowned, and more robust than in *Paratylopus cameloides*. It has two roots, the posterior of which is strongly developed on the inner side. In spite of its fore-and-aft straightness, an asymmetrical appearance is caused by a marked constriction throughout the whole of the anterior portion.

The curvature of the posterior crescent is concentrated at the tooth corner, resulting in a straight posterior edge and a broad, slightly convex inner wall. The posterior valley appears only near the base of the crown. The most unusual character is the anterior narrowing of the tooth. This causes a compression of the crescent and creates a broadly concave inner wall, thus thrusting the anterior pit backward against the median crest. The external valley so well developed in *P. cameloides* and in *O. floridanus* is absent in the Tick Canyon specimen, its place being taken by the internal constriction noted above. The posterior pit is large and pear-shaped, and is situated centrally within the basin, as contrasted with its extreme posterior position in *P. cameloides*.

The narrow, sharp mesostylid is exceeded in prominence by a strong parastylid, hooklike in section. A corresponding prong on the interior corner is slightly less developed than the parastylid. Broad, low median ribs, extending downward from the posterior and anterior crests, mark the outer surface. No cinguli are present.

The deciduous tooth is a typical three-lobed fourth premolar, with very strong constrictions between the lobes. In shape it is not unlike the corresponding tooth in *Procamelus coartatus* Stirton,[72] although it is smaller in size.

Discussion

The teeth are referred to *M. californicus* not only because they were collected in the same stratigraphic horizon as the type, but because they have characters suggesting a comparable stage of evolution among the Camelidae. Although no mandibular material is available in the type specimen, the size, shape, and robust build of the permanent fourth premolar indicate rather primitive features characteristic of the skull described by Maxson.

[67] J. H. Maxson, Carnegie Inst. Wash. Pub. No. 404, paper VII, pp. 106–109, 1930.
[68] W. D. Matthew, Bull. Amer. Mus. Nat. Hist., vol. 50, pp. 191–193, 1924.
[69] G. G. Simpson, Florida Geol. Surv. Bull. 10, pp. 35–37, 1932.
[70] O. A. Peterson, Ann. Carnegie Mus., vol. 2, p. 446, 1904.
[71] J. L. Wortman, Bull. Amer. Mus. Nat. Hist., vol. 10, pp. 117–120, 1898.
[72] P. C. Henshaw, Carnegie Inst. Wash. Pub. No. 514, paper I, pp. 21–22, 1939.

It seems worthy of note that certain questions pertaining to the ancestry of *M. californicus* are clarified by the new information on the age of the strata in which it occurs. An age determination as upper lower Miocene rather than upper Miocene, as based on diagnostic equid and oreodont material, furnishes the explanation for the anomalous situation noted by Maxson,[73] wherein the Tick Canyon camel appeared to be more closely related to John Day and White River types than to *M. tenuis* and *M. longiceps* from the Sheep Creek beds of Nebraska. Moreover, *M. californicus*, which seems to have more primitive features than *M. transmontanus*, occurs in beds now known to be older than Mascall, from which the genotype is recorded. A late lower Miocene age thus satisfies fully all the conflicting stratigraphic and biologic evidence.

Comparative measurements (in millimeters)

1. (?) *Miolabis californicus* Maxson, C.I.T. No. 2682.
2. *Miolabis tenuis* Matthew, A.M. No. 18965.*
3. *Paratylopus cameloides* (Wortman), C.I.T. No. 128.
4. *Oxydactylus floridanus* Simpson, F.S.G.S. No. V-5238.†
5. *Oxydactylus longipes* Peterson, Car. Mus. No. 918.‡
6. *Procamelus coartatus* Stirton, C.I.T. No. 2316.§

	1	2	3	4	5	6
$P\bar{4}$, anteroposterior diameter	13.0	9‖	11.4	13.5	12	11.2
$P\bar{4}$, transverse diameter	6.7	6‖	5.3	7.5	7	5.5

	M. californicus (C.I.T. No. 2683)	*P. coartatus* (C.I.T. No. 2319)
$Dp\bar{4}$, anteroposterior diameter	19.2	25.5
$Dp\bar{4}$, transverse diameter, anterior lobe	5.1	5.7
$Dp\bar{4}$, transverse diameter, middle lobe	5.8	7.2
$Dp\bar{4}$, transverse diameter, posterior lobe	6.1	6.8

* W. D. Matthew, *op. cit.*, pp. 191–193, 1924.
† G. G. Simpson, *op. cit.*, p. 37, 1932.
‡ O. A. Peterson, *op. cit.*, p. 446, 1904.
§ P. C. Henshaw, *op. cit.*, p. 22, 1939.
‖ Approximate.

[73] J. H. Maxson, *op. cit.*, p. 108, 1930.

Plate 1

Parahippus maxsoni, n. sp.

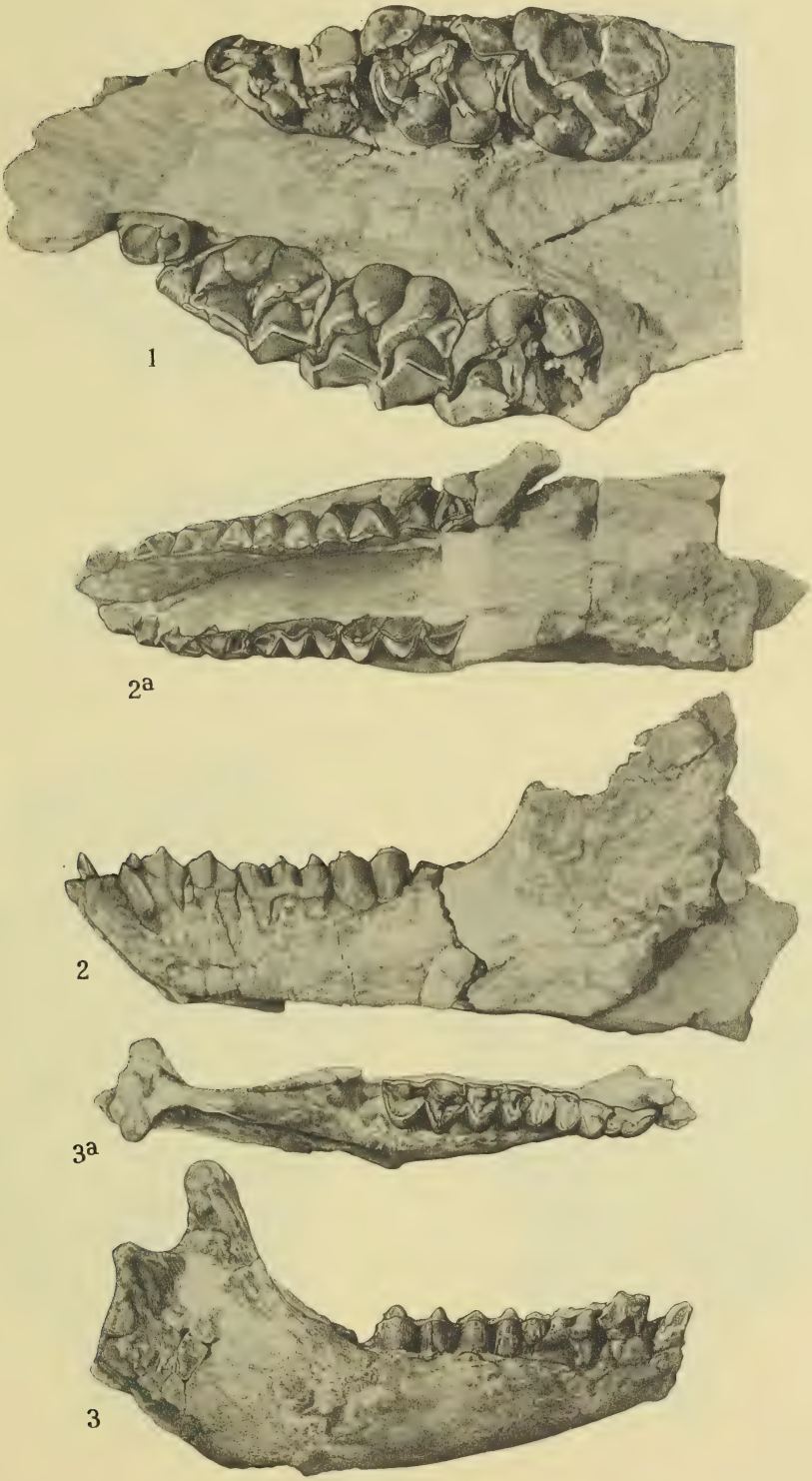
Fig. 1. Type specimen, No. 1385, palate, with deciduous dentition, $Dp\underline{1}$–$Dp\underline{4}$, occlusal view. × 1.

Merychyus calaminthus, n. sp.

Figs. 2, 2*a*. Imperfect mandible with lower dentition, No. 1384. Fig. 2, lateral view; fig. 2*a*, occlusal view. × 1.

Figs. 3, 3*a*. Mandible and lower dentition, No. 1829. Fig. 3, lateral view; fig. 3*a*, occlusal view. × 1.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Miocene, Tick Canyon, California.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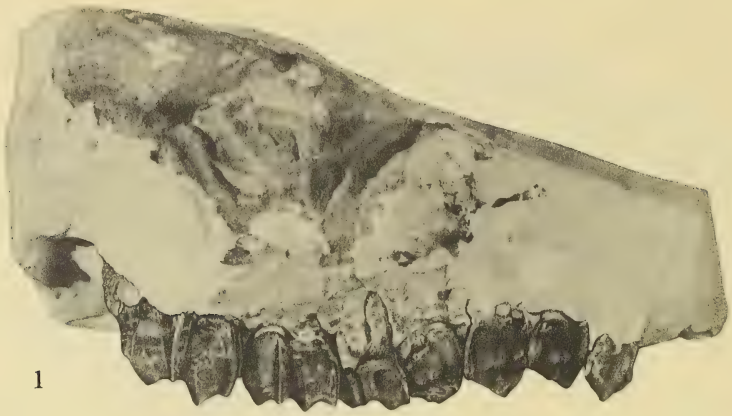


1

1a

2

2a

Plate 2

Merychyus calaminthus, n. sp.

Figs. 1, 1*a*. Cotype, incomplete skull and upper dentition, No. 1382. Fig. 1, lateral view; fig. 1*a*, occlusal view. × 1.

Figs. 2, 2*a*. Cotype, middle and posterior part of skull, No. 1382. Fig. 2, dorsal view; fig. 2*a*, ventral view. × 1.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Miocene, Tick Canyon, California.

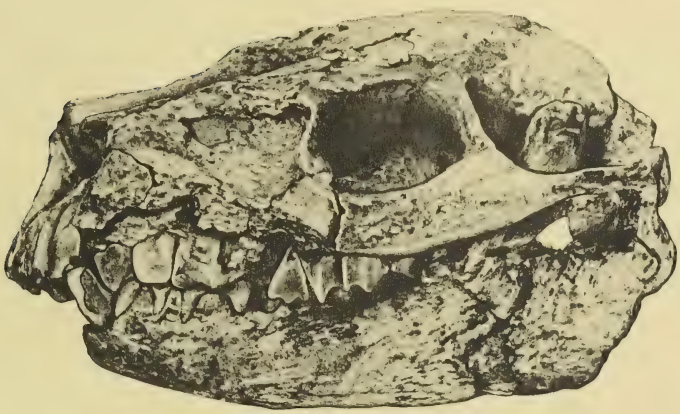
Plate 3

Merychyus calaminthus, n. sp.

Figs. 1, 1*a*. Cotype, skull and lower jaw, No. 1829. Fig. 1, anteroexternal view; fig. 1*a*, dorsal view. × 1.

Calif. Inst. Tech. Vert. Pale. Coll.
Lower Miocene, Tick Canyon, California.

1a



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